The sustainable refurbishment of abandoned industrial sites through smart adaptive reuse strategies. A Design Criteria System (DCS) for urban regeneration of marginal contexts.

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Abstract

The fragmented urban structure of contemporary metropolises caused by uncontrolled expansionist phenomena, and the economic and productive crisis of the last twenty years have led to social problems and the emergence of satellite districts physically separated by unused empty places. Many urban voids in the suburbs of modern cities concern disused and abandoned industrial sites. Therefore, there is a growing necessity to formulate innovative and sustainable strategies for urban regeneration, which provide, in the preliminary design phase, intuitive and schematic information and instructions to develop future smart green cities, facilitating stakeholders' decisions. Adaptive reuse models contribute to achieve this purpose, transforming metropolis latent resources in new and comfortable liveable and attractive sites, satisfying current community needs. These interventions allow to promote feasible refurbishment actions, converting obsolete volumes in futuristic architectures with multiple functions in order to extend building useful life. In particular, the thesis focuses on the analysis and evaluation of functional and spatial transformation potentials of five historic and contemporary dismissed industrial factories in Bari periphery, through the structuring of a weighted radio-centric multicriteria model, the Design Criteria System (DCS), which contains all the features influencing adaptive reuse processes. The data extracted from each selected case study are catalogued and enclosed in a descriptive table. The application of Decision Support Systems facilitates the classification of functional reuse alternatives hypothesized for each industrial context, evaluating their effectiveness on the basis of independent parameters. The insertion of building cataloguing table input data into the DCS structure and the identification of cause-and-effect relationships between attributes activate a process of automatic selection and characterization of the adaptive reuse strategy, extrapolating the features involved in that specific conversion circumstance and measuring the intervention feasibility coefficient (f) and risk entity (r) through the sum of the components weights highlighted. The proposed model can assist stakeholder's choices in complex decision-making contexts and represents a consistent and original tool to preliminary assess future possible regeneration scenarios, reducing urban sprawl phenomena and displaying with intuitive flowcharts feasible conversion policies and risks that could incur during planning, construction and maintenance activities.

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2020

Corrado Vizzarri

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D.R.R.S.

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Doctor of Philosophy in Risk and Environmental, Territorial and Building Development

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Coordinator: Prof. Michele Mossa

XXXIII CYCLE

ICAR/10 - Built Environment

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Department of Civil, Environmental, Land, Building Engineering and Chemistry

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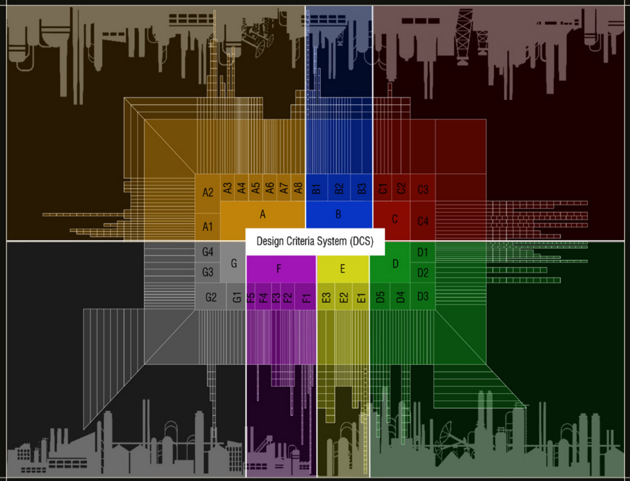

Politecnico di Bari

LIBERATORIA PER L'ARCHIVIAZIONE DELLA TESI DI DOTTORATO

Al Magnifico Rettore
del Politecnico di Bari

Il sottoscritto VIZZARRI CORRADO nato a BARI il 03/08/1992

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iscritto al 3° anno di Corso di Dottorato di Ricerca in Rischio, Sviluppo Ambientale, Territoriale ed Edilizio ciclo XXXIII

ed essendo stato ammesso a sostenere l'esame finale con la prevista discussione della tesi dal titolo:
The sustainable refurbishment of abandoned industrial sites through smart adaptive reuse strategies. A Design Criteria System (DCS) for urban regeneration of marginal contexts.

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Coordinatore: Prof. Michele Mossa

XXXIII CICLO ICAR/10
Architettura Tecnica

DICATECh
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Il recupero sostenibile di siti industriali abbandonati attraverso strategie innovative di riuso adattivo. Un sistema di progettazione delle attività (DCS) per la rigenerazione urbana di contesti marginali.

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EXTENDED ABSTRACT *(eng)*

Abandoned industrial areas are increasingly being taken as a starting point to ensure new standards of liveability in urban suburbs and new sustainable structures of contemporary metropolitan cities. The preservation and reuse of abandoned warehouses play an important role in the urban regeneration processes and help to meet the growing needs of contemporary society. The phenomenon of the conversion of the city's periphery concept has never been exhausted. Smart cities, in fact, have begun to set urban policies to encourage the application of adaptive reuse strategies in order to increase the life cycle of buildings. The increase in building transformation activities has strongly reinforced the view that the application of reuse strategies allows to achieve sustainability goals.

Adaptive reuse is a sustainable strategy that promotes the enhancement of urban planning asset and creates processes for revitalizing brownfield sites, with the aim of creating a resilient architecture. This modern way of action on disused urban contexts not only promotes the regeneration of unnecessary volumes and spaces, but also contributes to the improvement of the quality of life within the neighbourhood.

In recent years, many authors have studied the theme of adaptive reuse. Experts in the field of restoration, sustainability and construction have led discussions and analyses on methods to increase the recovery potential of the building, through choice factors. The use of Decision Support Systems (DSSs) helps stakeholders in the design, management, control and implementation phases of the work. These approaches, based on multicriteria analysis, are applied in many fields of architecture and engineering to evaluate the best design solutions that can be adopted in a specific con-

text. Organizing strategies to define universal industrial complex recovery procedures requires an accurate analysis of the design criteria that most affect building envelope transformation activities. The decision-making process, for interventions that allow to regenerate the existing, is complex, because there are multiple figures and factors that condition and modify the planning of the time steps to be predicted for their realization. Innovative adaptive reuse strategies allow to extend the useful life of buildings without going through their demolition.

Building conversion processes also require the analysis of a wide range of dependent and independent factors. The consideration of some factors in relation to others greatly influences the transformations within the building envelope, as well as involves different social, functional, economic and technological scenarios. In addition, during the recovery phases of the building, obstacles can be found that slow down the assumed procedures. There is, therefore, the necessity to structure a system of rules and strategies to facilitate the choices of intervention on the existing one.

The research presented in this doctoral work investigates the multicriteria methods of selection and evaluation of adaptive reuse interventions for decommissioned industrial buildings in order to consider all possible factors involved in building conversion processes. It contributes to conceive a universal strategy system for the recovery of the existing decommissioned, based on first-degree variables. Studies carried out during the doctoral period are aimed at the formulation of a multicriteria system of choice containing interconnected factors and parameters with a propensity to the development of preliminary strategies of adaptive reuse to support the conversion interventions of abandoned or decommissioned industrial obsolete sites. On this way of thinking, a radio-centric multicriteria design system (Design Criteria System - DCS) for data management and evaluation of construction transformation interventions is presented. The aim of the research converges in modelling different adaptive reuse strategies, based on a solid analysis of the physical, economic, functional, technological, social, legal and political factors that most affect the recovery phases. The system facilitates the choices of stakeholders by promoting scenarios that govern the construction phases and the modalities of intervention to be performed according to

population needs. Attributes and sub-attributes are selected through a thorough analysis of the literature in the field of urban regeneration and organized into seven main categories representing the project analysis issues on which developing the strategic intervention choices. This model, based on quantitative and qualitative input data, structures the intervention strategy, assessing its effectiveness. The innovation of this multi-variable approach lies in the possibility of framing, at the preliminary stage of design, a strategic scheme of activities for the refurbishment of decommissioned building envelopes. In particular, each individual component of the model has a weight and an identity code, making the system easy to understand for stakeholders.
On the basis of this, the research is divided into points. Firstly, a critical state-of-the-art review is carried out on the topic of adaptive reuse and existing multicriteria models of choice. Subsequently, factors that affect building recovery processes are selected. Last but not least, the methodological approach of defining and managing the multicriteria design system, selecting effective intervention scenarios through Decision Support Systems and validating the DCS with already patented evaluation models, is implemented. This procedure allows, at the preliminary design stage, to have an overview of the building transformation strategies even before intervening on the building itself, considering the related risks and constraints.
The functionality of the multicriteria design system in supporting decision-making processes can limit the phenomenon of uncontrolled urban sprawl and implement sustainable strategies aimed at the refurbishment of the abandoned existing structures and the promotion of feasible urban regeneration policies to transform industrial suburbs.

key words

Adaptive reuse, Design Criteria System (DCS), Building adaptation, Multi-Criteria Decision-Making Analysis (MCDMA), Industrial architecture, Refurbishment interventions

EXTENDED ABSTRACT *(ita)*

Le aree industriali abbandonate vengono prese sempre di più come punto di partenza per garantire nuovi standard di vivibilità nelle periferie urbane e nuovi assetti sostenibili delle città metropolitane contemporanee. La conservazione e il riuso di capannoni abbandonati gioca un ruolo importante nel processo di rigenerazione urbana e contribuisce a soddisfare i sempre più crescenti bisogni della società. Il fenomeno della riconversione del tessuto cittadino delle periferie non si è mai esaurito, al contrario, le città hanno incominciato ad impostare politiche urbanistiche atte a favorire l'applicazione di strategie di riuso adattivo per poter incrementare il ciclo di vita degli edifici. L'aumento delle attività di trasformazione edilizia ha fortemente consolidato il pensiero che l'applicazione di strategie di riuso consente di raggiungere obiettivi di sostenibilità.

Il riuso adattivo è una strategia sostenibile che promuove il potenziamento dell'assetto urbano e dà vita a processi di rivitalizzazione delle aree dismesse, nell'ottica di creare un'architettura resiliente. Questo moderno modo di intervenire sull'esistente in disuso non solo promuove la rigenerazione di volumi e spazi inutilizzati, ma contribuisce al miglioramento della qualità della vita all'interno del quartiere.

Molti sono gli autori che, negli ultimi anni, hanno studiato il tema del riuso adattivo. Esperti nel campo del restauro, della sostenibilità e dell'edilizia hanno guidato discussioni ed analisi sui metodi per aumentare le potenzialità di recupero dell'edificio, mediante fattori di scelta. L'utilizzo di metodi di supporto alle decisioni aiuta gli stakeholders nelle fasi di progettazione, gestione, controllo e realizzazione dell'opera. Questi approcci, basati su analisi multicriteri, vengono utilizzati in molti campi

dell'architettura e dell'ingegneria per poter valutare le soluzioni progettuali che meglio possono essere adottate in un determinato contesto. Organizzare le strategie utili alla definizione di procedure universali per il recupero dei complessi industriali richiede un'analisi accurata dei criteri di progettazione che maggiormente influiscono sulle attività di trasformazione dell'involucro edilizio. Il sistema di decisioni, per interventi di rigenerazione dell'esistente, risulta complesso in quanto sono presenti molteplici figure e fattori che condizionano e modificano la programmazione degli step temporali da prevedere per una loro realizzazione. Strategie innovative di riuso adattivo consentono di estendere la vita utile degli edifici senza andare incontro alla loro demolizione.
I processi di riconversione edilizia richiedono, altresì, l'analisi di un ampio spettro di fattori dipendenti ed indipendenti. Considerare alcuni dei fattori rispetto ad altri influenza notevolmente le trasformazioni all'interno dell'involucro edilizio, nonché comporta scenari sociali, funzionali, economici e tecnologici differenti. In aggiunta, durante le fasi di recupero del fabbricato, si possono riscontrare ostacoli che rallentano l'iter procedurale presupposto. C'è bisogno, dunque, di un sistema di regole e strategie atte a facilitare le scelte d'intervento sull'esistente.
La ricerca presentata in questo lavoro dottorale indaga i metodi multicriteri di selezione e valutazione di interventi di riuso adattivo per edifici industriali dismessi al fine di considerare tutti i possibili fattori che intervengono nei processi di conversione edilizia, ideando un sistema di strategie universali per il recupero dell'esistente dismesso, fondato su variabili di primo grado. Gli studi effettuati nel periodo di dottorato sono rivolti alla formulazione di un sistema multicriteri di scelta contenente fattori e parametri interconnessi fra loro con una propensione allo sviluppo di strategie preliminari di riuso adattivo di supporto agli interventi di conversione di siti industriali abbandonati o dismessi. Su questa linea d'onda viene presentato un sistema di progettazione multicriteri (Design Criteria System - DCS) radiocentrico di gestione dati e valutazione degli interventi di trasformazione edilizia, con l'obiettivo di modellare diverse strategie di riuso adattivo, basate su una solida analisi dei fattori fisici, economici, funzionali, tecnologici, sociali, legali e politici che condizionano maggiormente le fasi di recupero. Il sistema facilita le scelte degli stakeholder promuovendo scenari che regolamentano le

fasi di realizzazione dell'opera e le modalità di intervento da eseguire a seconda delle esigenze sociali da soddisfare. Gli ambiti ed i micro-ambiti vengono selezionati mediante un'accurata analisi della letteratura nell'ambito del recupero e della rigenerazione urbana ed organizzati in sette categorie principali rappresentanti le tematiche di analisi del progetto su cui indirizzare le scelte strategiche di intervento. Questo modello, sulla base di dati quantitativi e qualitativi di input, costruisce la strategia di intervento, valutandone l'efficacia. L'innovazione di questo approccio a più variabili risiede nella possibilità di inquadrare, in fase preliminare di progettazione, uno schema strategico di attività per il recupero di involucri edilizi dismessi. In particolare, ogni singolo componente del modello presenta un peso e un codice che li contraddistingue, rendendo il sistema di facile intuizione per gli stakeholder.
Sulla base di quanto detto, la ricerca è stata suddivisa per punti: per prima cosa si è svolta una revisione critica dello stato dell'arte in merito al tema del riuso adattivo e dei modelli di scelta multicriteri esistenti; successivamente si è passati alla selezione dei fattori principali che influiscono sui processi di recupero edilizio. In ultimo luogo si è implementato l'approccio metodologico improntato alla definizione e gestione del sistema di progettazione multicriteri e alla selezione di scenari di intervento efficaci tramite sistemi di supporto alle decisioni, nonché alla validazione del DCS con modelli di valutazione già brevettati. Questa procedura consente, in fase preliminare di progettazione, di avere un quadro generale delle strategie di trasformazione edilizia già prima di intervenire sull'edificio stesso, considerando rischi ed interruzioni ad esse correlate.
La funzionalità del sistema di progettazione multicriteri nel supportare i processi decisionali può limitare il fenomeno dell'espansione urbana incontrollata e implementare strategie sostenibili mirate al recupero dell'esistente abbandonato ed alla promozione di politiche di rigenerazione urbana delle periferie industriali.

key words
Adaptive reuse, Design Criteria System (DCS), Building adaptation, Multi-Criteria Decision-Making Analysis (MCDMA), Industrial architecture, Refurbishment interventions

INDEX

0. INTRODUCTION

The phenomena of uncontrolled expansion and development of contemporary metropolitan cities characterized by an increase of new construction in urban marginal areas have led to an exponentially marked fragmentation of the local morphological, infrastructural and social structure. Moreover, the current economic crisis affecting the productive sectors and the development of the advanced tertiary sector as the new driving force of the world economy have fostered processes of industrial divestment with consequent environmental and social repercussions. Indeed, urban sprawl creates completely isolated microcosms far from the consolidated urban tissues with poor amenities useless to meet the inhabitant's primary needs.

At the same time, these vast empty spaces can become concrete and real opportunities for renewal and revaluation of the city's suburbs, providing the creation of new spaces for aggregation, social inclusion and attractive services and transforming these abandoned places from static urban wrecks to focal points of interest in order to develop modern and innovative integrated regeneration policies of peripheries. However, the reuse and adaptation processes are complex and dynamic, since they not only involve a large number of stakeholders, but consider a multiplicity of criteria, sub-criteria and iterations difficult to manage simultaneously, greatly lengthening decision-making processes, if effective cataloguing and multi-attributes screening tools are not forecasted.

Nowadays, adaptive reuse models represent attractive alternatives to new constructions in terms of sustainability and circular economy and effective re-functionalisation and refurbishment processes for optimizing latent performances of the existing built assets and promoting feasible and effective conversion scenarios of disused production sites. Focusing the attention on this modern procedure for the recovery and transformation of unused and marginal industrial resources, the need of proposing a methodological approach emerges with the purpose of formulating, in the preliminary design stages, reliable and consistent adaptive reuse strategies and building classification procedures to reduce urban sprawl and simplify decision-making procedures. On the contrary, many experts and professionals prefer to demolish industrial settlements already rooted in urban contexts to introduce new technologically advanced volumes, without thinking about the historical, architectural and social values that each decommissioned production site incorporates.

In recent years, adaptive reuse interventions on abandoned industrial contexts have led to a significant change in the urban structure of many cities, establishing and fortifying the connections between the historical and contemporary built spheres. Furthermore, the topic of adaptive reuse has been widely investigated by the literature and international research groups with the aim to preserve and catalogue industrial archaeology design features and implement smart Decision Support Systems (DSSs) in order to easily rank and estimate functional conversion alternatives. The missing piece in the framework of the multicriteria adaptive reuse evaluation tools concerns the absence of a calculation model that not only encompasses macros and microareas affecting building transformation activities, but also that extrapolates quantitative data and flow diagrams of punishable industrial regeneration strategies.

Indeed, the integration of the existing Multi-Criteria Decision-Making Analyses (MCDMA) with a smart tool for adaptive reuse strategy computation and selection could be a possible and practical solution to assess feasible intervention policies in order to increase liveability, security, spaces quality and social inclusion.

After a first mention on the issue of deindustrialization in the different European urban contexts and the explanation of actual experts debate about demolish or not to demolish existing buildings (chapter 1), an in depth and accurate literature review about the evolution of smart cities, the benefits and constraints of adaptive reuse, the key design factors and risks that may affect building adaptation processes and the MCDM approaches for estimating building conversion potentials and project solutions has been carried out. Chapter 3 describes the methodological approach proposed for the implementation and composition of the hypothesised Design Criteria System (DCS), as well as the mathematical formulation and sequences of the selected Decision Support System (DSS) to rank adaptive reuse alternatives. The methodology consists of multiple and linked steps, methods and multicriteria evaluation tools tested on five dismissed industrial case studies located in Bari periphery: three of these sit in the ASI Consortium of Bari-Modugno, the other two production contexts occupy the adjacent STANIC district. The abandoned industrial lots analysed embody different dimensional characteristics, levels of degradation of existing components and architectural, formal and historical values. The process of selecting and classifying functional and compositional alternatives using the Multi-Attribute Value Theory (MAVT) and Optimised Analytic Hierarchy Process (O-AHP) decision support applications is explored in chapter 4. Instead, the chapter 5 delineates findings and discussions about the output data arisen from the DCS radio-centric model testing, providing comparisons and observations with outputs obtained by other patented multi-attributes evaluation tools, in order to provide conclusions and future possible developments of the hypothesised innovative framework (chapter 6).

1. THE PHENOMENON OF INDUSTRIAL DECOMMISSIONING IN URBAN CONTEXTS

1.1 The problem of deindustrialisation for sustainable cities development

In the marginal metropolitan areas, the uncontrolled expansionism of new construction has led to the creation of sites without its own urban connotation. In conjunction with this phenomenon, the generation of urban voids has resulted in the fragmentation of urban morpho-compositional tissue. In particular, the process of de-industrialisation and decommissioning of industrial areas has further disrupted the uneven fringe structure of modern cities.

The term "industrial disposal" refers to the process of decommissioning, partial or total, of entire sites, as well as of building blocks or individual sheds linked to productive activities (Dansero, 1993). The connotation "disused area" includes a large number of situations very often related to formal and functional aspects that, over the years, have become obsolete in the social and urban mechanisms of modern cities, requiring redevelopment and recovery interventions. A second recurring word in the context of industrial decommissioning is related to the meaning of 'polluted site'. With this term professionals identify all the areas that need remediation. An industrial site that has characters of abandonment and pollution in urban and non-urban settings is called brownfield (Mastria, 2016) (Figure 1.1-1).

The phenomenon of deindustrialisation develops in different ways and times depending on geographical areas and industrial sectors. In the past, this process had been caused by the cessation or transfer of a productive activity to the new peripheries of contemporary cities.

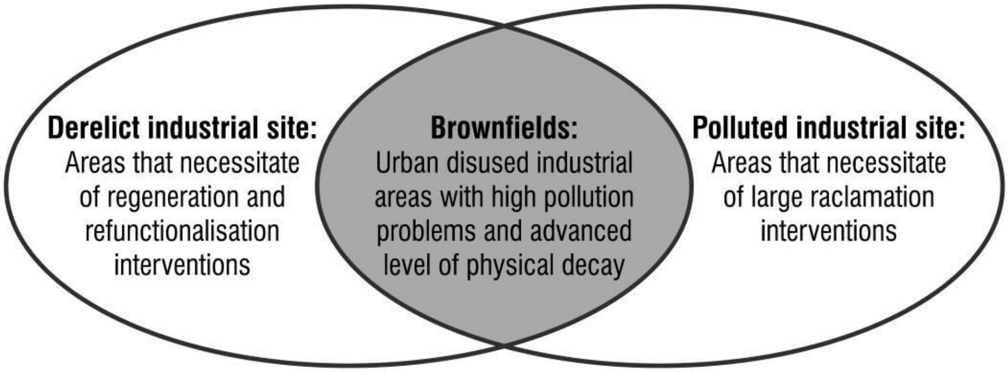


Figure 1.1-1 Derelict industrial site, polluted industrial site and brownfields meanings and relationships (Mastria, 2016).

Since the 1930s, the relocation of production activities to peripheral metropolitan areas had reduced construction congestion in city centres. The real industrial decommissioning period started in the 1970s. This first process of abandonment and use of industrial contexts involved the mining, industrial and port cities of Central Europe and the central and Atlantic regions of the United States. Since the end of the same decade, the phenomenon had also developed in the regions of southern and Mediterranean Europe such as the south of France, northern Italy and the regions of Bavaria (Dansero, 1993).

Considering the productive factories and warehouses typologies point of view, the first industrial plants to be decommissioned belonged to the driving sectors and manufacturing contexts that characterised the Industrial Revolution. Metallurgical, steel, shipbuilding and textiles production were hit hard by the economic crisis of the 1970s, causing the abandonment of large production areas that formed the skeleton of the urban structure of the 19th century (Monti, 1989). The phenomenon of deindustrialisation, therefore, marked the end of the historical era when heavy industry played a leading role in the economic development of European cities (Travascio, 2007). In most European countries, the presence of decommissioned productive contexts has been recognised as a problem for future configurations of metropolitan cities. However, there are few contexts in which the analysis of dismissed industrial areas has been drawn up to determine the progress of the phenomenon, in terms of covered area. The Austrian Federal Environment Agency (Austrian Federal Environment Agency, 2002) summarizes data on the extent of decommissioned industrial sites in European industrial countries, highlighting the number of abandoned and contaminated factories and sheds (Table 1.1-1) (Figures 1.1-2; 3).

Nation	Number of industrial contaminated sites	Dismissed industrial sites (ha)	Geographical concentration
Belgium	58528	14500	(Fiandre and Vallonia)
France	300000	20000	Nord-Pas-de Calais, Lorraine, Rhone-Alpes
Germany	362000	128000	East Germany, Berlin, Ruhr, Saar
Italy	50000	8500	Lombardia (Milan area), Piemonte, Veneto, Campania, Calabria
Holland	120000	11000	Rotterdam, Amsterdam
Great Britain	100000	39600	Mersey Tyneside, Yorkshire Midlands, South Wales, Scotland, London

Table 1.1-1 Overview of derelict industrial sites and contaminated areas in Europe (Austrian Federal Environment Agency, 2002).

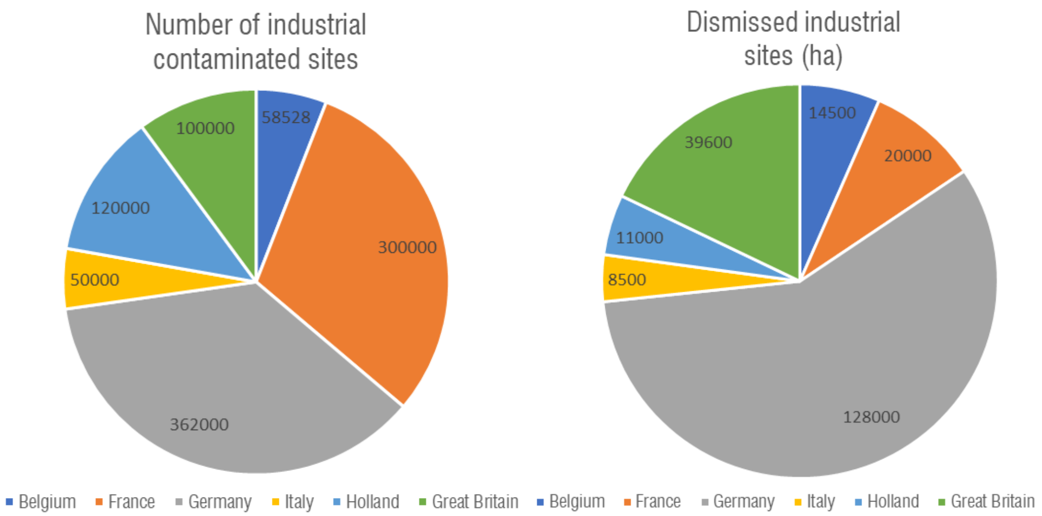


Figure 1.1-2 Pie charts: number of industrial contaminated sites (left) and dismissed industrial sites in hectares (ha) (right).

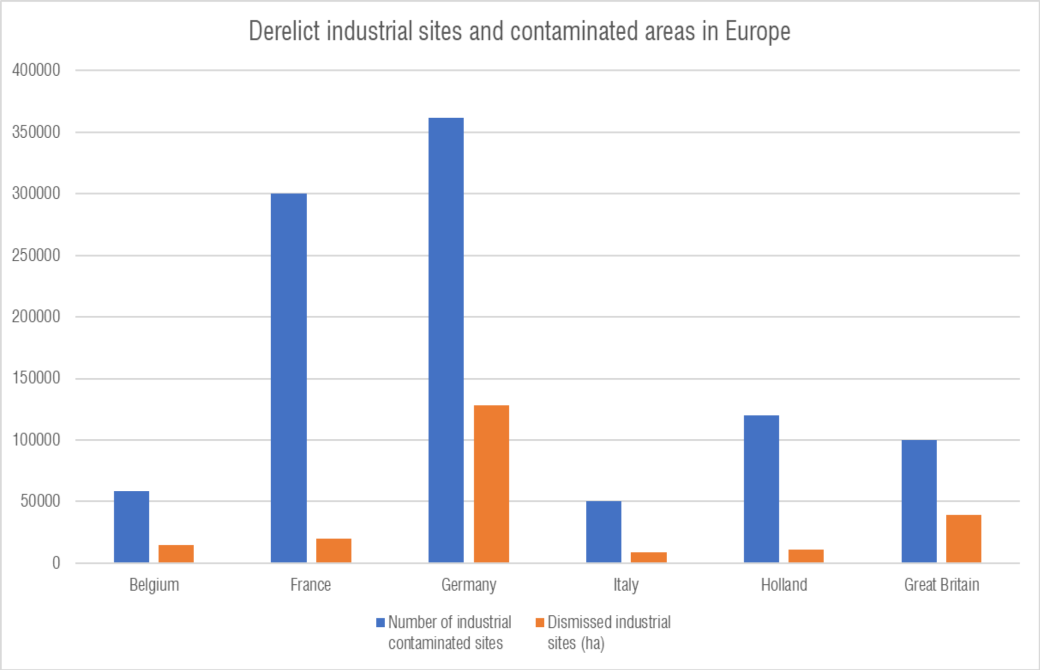


Figure 1.1-3 Histogram of derelict industrial sites and contaminated areas in Europe (Austrian Federal Environment Agency, 2002).

As it is possible to notice from the two graphs, the nations that have suffered mostly the industrial divestment match the areas of greatest development in the secondary sector during the period of Industrial Revolution. In particular, Germany, France and Great Britain have the largest number of contaminated industrial sites, 362.000, 300.000 and 100.000 respectively, and high values of brownfields, 128.000 ha, 20.000 ha and 39.600 respectively (Austrian Federal Environment Agency, 2002).
In Italy, the theme of brownfield sites has occupied the urban and architectural scene for about two decades. According to ISTAT data (ISTAT, 2012) decommissioned industrial buildings in Italy account for 3% of the entire national area. In the late 1970s and early 1980s, the issue of fabrics disposal began to arouse increasing interest, becoming a central theme of the debate on urban development in cities in the 1990s. This period coincided with the phase of population decline and depopulation of city centres due to the slowing down of the urban growth process and the abandonment of large productive portions of the city (Calderazzi, 2012; D’Agostino, 2003).

Travascio (Travascio, 2007) divides the debate about the phenomenon of deindustrialization in Italy into three evolutionary steps. The first phase, limited to the years between 1980 and 1990, encompasses the initial period of industrial divestment in Italy, where researchers began to take an interest in this emerging and exponential phenomenon and study the problems associated to this. In this time frame, the scientific debate lays the groundwork for quantifying the extent of the phenomenon, building a cognitive framework of abandoned industrial sites. The second phase, enclosed in the decade of the 1990s, affirms the need to intervene in brownfield sites to adopt urban regeneration strategies in the city context. During this period, the discussion focused on the investigation of the causes of warehouses disposal and, in particular, on the advent of tertiary services and technological innovation in social day-to-day life (Pugliese, 1993). The third phase, corresponding to the new Millennium, assesses the possibilities of intervention for the conversion of decommissioned sites. In the latter step, scholars became aware of the reuse potential of unused industrial spaces and volumes, activating sustainable transformation policies.
Nowadays, decommissioned industrial buildings make up a significant part of the architectural building heritage, particularly in historic industrialised countries. In the contemporary city, the phenomenon of the decommissioning of factories is strictly connected to the new needs of modernization of services and infrastructure, marked by faster times of technological innovation and the transition from manual production to an automated and digital manufacture of industry 4.0. Unused industrial sites define urban gaps and fragmentary structure of cities. At the same time, they conceal spaces full of content, meanings, memories and buildings characterised by particular historical and architectural value (Fubini, 1996). These derelict areas are seen as empty envelopes available to imprint urban regeneration actions (Bobbio, 1999). Many European metropolis (London, Paris, Barcelona, Copenhagen, Amsterdam, Manchester, Lisbon) and Italian cities (Milan, Turin, Genoa, Venice, Parma, Rome, Naples, Catania, Bari) have introduced urban reorganisation measures by recovering abandoned industrial contexts in order to activate sustainable urban regeneration solutions. The exponential interest on the subject of industrial divestment is therefore explained in the

need to adopt intelligent scenarios of intervention on the existing urban fabric, with a high historical and architectural character. These sustainable actions can be interpret as the compensation of injured territory by ancient decisions and irresponsible policies that have exploited it at the expense of the community and the starting point to develop new policies of buildings conversion (Spaziante, 2000). Engineers, architects, urbanists and other professional figures in the field of refurbishment and sustainable development are beginning to consider the abandoned industrial sites as a concrete opportunity to reorganize the modern city (Gregotti, 1990) from the point of view of urban planning, building preservation, life quality and economic opportunities (D'Agostino, 2003). The process of sheds disposal is no longer seen as a threat, but as an opportunity to change the city morphology starting from empty and unused contexts already rooted in it.

1.2 Causes of deindustrialisation

The decommissioning of industrial areas is closely linked to the evolution of society, people needs over time and the new emerging functions in the modern urban fabric. The contemporary city, in fact, is a conglomerate of volumes and spaces that man organizes and transforms over the years in order to meet the current needs of the population. The morphological and urban dynamism of the fabrics that compose spaces generates, at the same time, heterogeneity and social, infrastructure and economic fragmentation. Unmanaged and unplanned development actions of the territory and city, low attention to environmental issues and impacts resulting from the disposal of production facilities and processes economically beneficial for companies, but onerous for communities, are some of the causes that have led to the emptying of large outlying and peripheral urban portions and current soil pollution conditions.

Gargiulo and Battarra (Gargiulo & Battarra, 2002) in their studies concerning the processes of re-functionalization and transformation of decommissioned industrial areas summarize the causes of deindustrialisation in five key points:

a) The economic crisis of the 1980s involving the large production sectors of heavy industry. In addition to this socio-economic problem, the loss of employment due to emigration and population reduction in cities increase exponentially the number of brownfields;
b) The policies of territorial decentralisation of production sectors in urban suburbs and the consequent functional emptying of large consolidated areas of the building fabric. The physical separation of production phases and the spatial organization based on the specialization of the activities relocated in satellite cities fragment and disintegrate the historical concept of large industrial establishment, reducing the operational site capacity (Barosio, 2009);
c) The increasing of technological innovations in production mechanisms that have differentiated functional localizations (Smets, 1990; Spaziante, 1996) and the development of the tertiary sector, which has increasingly marginalised the secondary sector in the extreme suburbs of the modern metropolis (Pugliese, 1993). The production machine is deprived of its centrality in the economic growth of cities to make room for the virtual and entrepreneurial world;
d) Redefining industrial economic activities and reducing workers in secondary sectors caused by the advent of tertiarization. New services and job opportunities move the workforce towards contemporary scenarios different from the industrial production environment;
e) Customs protectionism policies on imports and limiting of domestic competition implemented by national governments.

Rowthorn and Coutts (Rowthorn & Coutts, 2004) identify five key socio-economic factors of deindustrialisation:

1) The reclassification of jobs from manufacturing to services caused by new trends relating to the tertiary sector;

2) The decline in the share of production in consumer expenditure due to a fall in manufactures prices;
3) The slower employment growth in the industrial sector than in innovative and technological services;
4) The negative effects of imports from lower-cost producers on manufacturing employment in developed countries;
5) Negative effects of lower rates of investment on manufacturing activities.

Donnarumma (Donnarumma, 2014), from the analysis of different scenarios of industrial disposal, has identified as the main causes of deindustrialization the "crisis of product", that is defined as the depletion by the market of the demand for an asset with the consequent inability of the sector to respond quickly to the changed needs of society, and the building obsolescence in relation to the continuous technical and functional progress. Buildings degradation can affect both physical parts of the structure, but also the planting, technological (machine), functional (workspaces and flows management) and organizational aspects. In addition, the high level of sites decay makes the building inadequate with regard to the protection of the health and safety of workers. Rowthorn and Ramaswamy (Rowthorn & Ramaswamy, 1997) focus their attention on the decline in investment in the production sector as the main factor of industrial disposal. Krugman (Krugman, 1996) analyses deindustrialisation as a “domestic distortion” that causes welfare losses due to positive wage ranges between manufacturing and services sectors. The immediate change in the city's economic hierarchies, no longer aimed at the production of material goods, but useful to develop services for the community, has significantly modified the social framework, as well as the demand and supply of primary goods. The rise in services employment sector has been accompanied by a decline of workers in manufacturing in all advanced economies. These changes are the basis of the slow and unstoppable abandonment of industrial sites that are unable to adapt to the new emerging socio-economic conditions. On the other hand, deindustrialization is not a negative phenomenon, but a natural consequence of sudden growth in advanced economies and smart services.

1.3 Impacts of unused industrial sheds in contemporary cities

The presence of big unused industrial areas in urbanized, peripheral and non-urbanised fabrics has significant impacts in social, environmental, architectural and economic aspects. Bianchi and Turturiello (Bianchi & Turturiello, 2016) synthesize the impacts of the abandonment of polluted industrial areas (Figure 1.3-1).

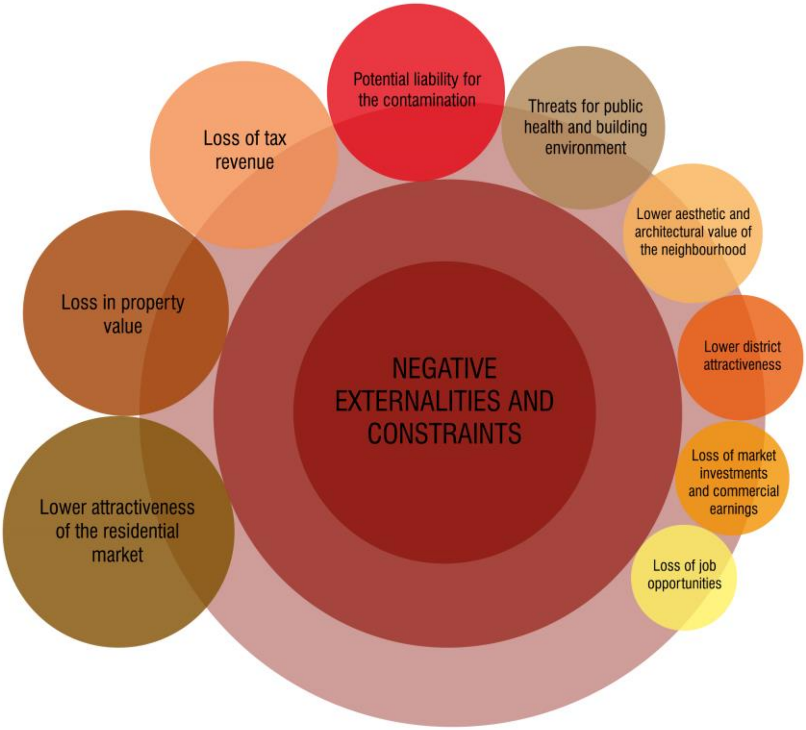


Figure 1.3-1 Cyclical graph of the negative externalities that a brownfield side can produce (Bianchi & Turturiello, 2016).

The cyclical trend of the graph shows how all the factors that a decommissioned industrial site can produce are individually correlated with each other by cause-and-effect relationships. The effects of deindustrialisation as unemployment, poverty, deskilling and role definition, and population health are strictly related to each other (Glasgow Centre for Population Health, 2014). In the majority of industrial countries and regions deindustrialisation damages health and slows improvements in life expectancy, causing an increasing of mortality. This phenomenon has affected the social fabric of countries and cities communities, increasing population distances and inequalities. As mentioned above, the impact of industrial divestment on society has greatly influenced the working world, especially considering that until the post-war period the secondary sector was driving the economy of the world's industrial powers. The menace of job insecurity has conditioned the sociology of industry, work and occupation, cause the disastrous effects of deindustrialization (Abanyam, 2014). Work affects personal and family life. Without work and monetary incomes, people can't guarantee high standards of living. The replacement of labour with machinery and the total decommissioning of industrial plants with the advent of automation, technological innovation and the service sector have greatly increased the level of unemployment of workers, who, reduced to automata specialised in individual productive activities, hardly find a new stable and waged job. Unemployment effects on society in most of situations involve in prostitution, crime, alcoholism, drug abuse, poverty and trafficking.

From a purely geographical point of view, the presence of large empty built industrial areas decreases social relations between neighbourhoods. Large cities are fragmented by the process of industrial decommissioning, creating scenarios of relocation of neighbourhoods. Cities in cities that on planning cartographies are included in the same metropolitan area, but physically constitute independent micro-worlds and often divergent scenarios in terms of quality of life and social hierarchies. The physical expansion of the city in the natural territory has led to the crisis of the classical structure associated with it in the past: the decline of the industrial system has transformed spaces, dissolving the principle of identity connected to the concept of place (Calderazzi, 2015).

From an environmental point of view, the disposal of large industrial containers, in most cases, leaves the territory in an advanced state of degradation and soil pollution. In particular, large steel, metallurgical, energy, manufacturing, chemical and petrochemical factories use highly polluting and harmful materials and production processes that damaged the surrounding natural environment. In some cases, the presence of these production organisms completely transforms the anthropogenic characteristics of a natural context. Once the industrial production cycle is over, the phenomenon of soil pollution does not stop, but remains in the territory until the implementation of site reclamation activities. The environmental impact of an abandoned industrial site is an obstacle to the development of sustainable cities in economic and spatial terms, not being able to actively intervene on it until preventive measures are taken to eliminate pollution for its future reuse.

In addition to the problem of polluted industrial sites, there is also the environmental impact of the use of harmful building materials. In fact, in the period of the industrial revolution the theme of sustainability had not yet been introduced into the constructive culture of the time. During the Industrial Revolution, the functionality and productivity of the factory was taken care of without considering the quality of the materials used to make it. The presence of asbestos affects not only the health of the environment, but also people health. The architectural degradation, generated by the abandonment and use of buildings, makes the existing technologies and plants obsolete, deteriorates the materials, bringing out the weaknesses of them, as well as the repercussions on the environment and human being (Donnarumma, 2014). From an architectural point of view, the presence in a neighbourhood of an abandoned industrial site reduces the aesthetic quality of the context, lowering the attractiveness of the area both from the activation of tourism policies and the real estate market (Bianchi & Turturiello, 2016).

The economic impacts of industrial decommissioning are of no less importance. In fact, two different categories of economic impact can be distinguished. The first relates to the loss of revenue due to the inactivity of the industrial site. The closure and divestment of productive activities weighs on the economies of the sector and on the Gross Domestic Product (GDP), as well as the economic conditions of people who have lost their jobs linked to the failed company. In addition, the physical building decay affects the site value, significantly decreasing the selling cost of the property. The second, however, concerns the significant costs for a possible sustainable recovery and adaptation of the area. This aspect is associated with the low attractiveness of the site in the real estate market (Bianchi & Turturiello, 2016). Stakeholders prefer to expropriate new areas to invest in the construction market rather than regenerate an outdated casing. This last point represents the heart of the current debate involving, on the one hand, promoters of modern cities development through expansionist policies aimed at the demolition of the existing to amplify spaces for new constructions and, on the other hand, professionals who consider the abandoned existing volumes as the starting point for adopting smart urban regeneration strategies to assess sustainability issues in marginal cities agglomerations.

1.4 Demolish vs reuse

In the last twenty years, the themes of the reclamation of polluted territories and the recovery of unused industrial buildings have given rise to a heated debate among professionals in the fields of architecture, engineering, urban planning and environmental protection regarding the possibilities of reusing urban voids for the activation of housing regeneration policies. The purpose of this current confrontation lies in mending the fabric of the city fragmented over time. It is, therefore, possible to identify two different currents of thought on this issue. The first is focused on the definition of sustainable city development strategies through actions involving the demolition of the existing and on the construction of new, technologically better-performing buildings. The second considers the recovery policies and redevelopment procedures of the disused building as a starting point for the definition of modern smart cities.

A key decision that owners and investors are confronted with, is whether to adapt the vacant built assets or demolish them (Bullen & Love, 2011a). In addition, there is a growing perception that it is cheaper to convert industrial buildings to new uses than to demolish and rebuild (Vanegas et al., 1995; Ball, 2002; Douglas, 2006). Ellison et al. (Ellison et al., 2007) suggest that reusing buildings to meet society needs and to increase sustainability issues are 12% more expensive than a standard reuse project. Kohler and Yang (Kohler & Yang, 2007) explain that refurbishment costs can be lower than the equivalent demolition and reconstruction investments. Thomsen and Van der

Flier (Thomsen & Van der Flier, 2006) point out that adaptation processes are preferable to demolition if environmental sustainability aspects and energy consumption can be satisfied. Shipley et al. (Shipley et al., 2006) consider reuse activities cheaper than to demolish and reconstruction when the existent presents structural quality, the borrowing cost is reduced, and contract periods are shorter. On the other hand, building owners and practitioners don't consider reuse activities as the turning point for city development. In fact, problems associated to health and people safety, maintenance costs, inefficiencies in spatial layout, risks and uncertainties can be arisen during the refurbishment of dismissed brownfields (Shipley et al., 2006; Remoy & Van der Voordt, 2007; Kurul, 2007; Bullen, 2007; Bullen & Love 2010).
Demolition processes occur when buildings no longer have any architectural value (Kohler & Yang, 2007). In most cases, at the same time, the expansionist aims and the economic profits associated with them lead the business client to consider the process of demolition and reconstruction of warehouses as the only solution available for the development of urbanized places. The prevalence of economic aspects and the market of the new on the disused built resources tend not to evaluate the historical importance and architectural iconicity that an abandoned industrial context possesses for the evolutionary memory of metropolis development in social culture. Douglas (Douglas, 2006) maintains that building architecture quality is an important feature to consider if the site conversion strategies converge in demolition interventions. According to Ball (Ball, 2002) it's preferable to refurbish a derelict industrial site than replace it because the quality of a new building may be worse than the older one. In contrast, O'Donnell (O'Donnell, 2004) asserts the performance superiority and the social value of new constructions respect older obsolete buildings.
Sometimes demolition is selected when building life expectancy of an existing building are less than a new one. The age of materials and their level of decay affect directly building maintenance costs of an adapted building and may be higher than those for a new volume. In addition, adapting existing factories generate less waste, use fewer materials and preserve site iconicity than demolition and rebuilding. Through literature review analyses, it's possible to understand that the opportunities

arisen by recovery interventions on the existing overbear those presented by demolition and reconstruction (Ball, 1999; Cooper, 2001; Kohler & Hassler, 2002; Petersen, 2002). Building adaptation processes offers a more efficient and effective process of dealing with buildings than demolition, because they reduce the amount of disturbance due to hazardous materials, preserving the embedded energy of the existing structure (Bullen & Love, 2011b) and without affecting its architectural importance and value to future generations.

1.5 Architecture resilience of derelict industrial contexts

In the context of metropolis development, the concept of architectural resilience of dismissed warehouses is a very innovative approach for future transformation and regeneration processes. As mentioned by Bottero et al. (Bottero et al., 2017) urban building resilience refers to the ability to absorb, adapt and respond to changes in an urban system, considering sustainability, governance and economic features. Holling (Holling, 1973) defines "resilience" as a measure that shows the system's ability to absorb and cope with changing circumstances. Another definition of resilience is given by Folke et al.. They assert that resilience is a "measure of robustness and buffering capacity of the system to changing conditions" (Folke et al., 2002). Fatiguso et al. (Fatiguso et al., 2017) introduce resilience as the capability of a system, a community or a society exposed to hazards to mitigate, change and recover from the effects in a rapid and efficient manner, by keeping its functions and structures. The Urban Land Institute defines resilience as "the ability to prepare and plan for, absorb, recover from, and more successfully adapt to adverse events" (Urban Land Institute, 2018). Resilience can be synthesized as the elasticity of a building, a community, or, more generically, a host to revert to the full operations of the status quo.
Urban systems and the environment change over time independently from external factors (Holling, 1973; Holling, 1996). Cities, nowadays, are segmented in terms of functions, districts and population. Urban sprawl increases this phenomenon, modifying completely the perception of periphery surroundings. Metropolis, characterised by

complex and dynamic composition, are increasingly facing challenges linked to the rapid population growth, society needs, climate changes and building decommissioning. In addition, buildings, especially in the industrial sector, become obsolete and under maintained, speeding up their disposal. According to Aytac et al. (Aytac et al., 2016) architectural resilience can be obtained through the implementation of smart approaches that allow to amplify building life cycle, introducing new functions based on people needs.

In the field of the obsolete built environment, it is possible to distinguish three different dimensions of resilience (Fatiguso et al., 2017):

a. Environmental resilience: it refers to the landscape ability to adapt to changing climatic conditions by reducing vulnerability to natural hazards;
b. Socio-cultural resilience: it considers the implementation of social cohesion and construction practises that create a sense of identity and awareness of abandoned industrial sites potentials;
c. Socio-economic resilience: it takes into account the relationship between services productivity and social life quality, in terms of resource management and population inclusion in decision-making processes.

Considering industrial derelict settlements, such aspects must be accounted to assess adaptive transformations of marginal voids, allowing social, economic and cultural continuous evolution processes. The concept of resilience, therefore, is attributable to the ability of the abandoned industrial building to be able to compensate social, cultural and functional shortcomings in the neighbourhoods through sustainable recovery and conversion activities with the aim of ensuring, in the future, services useful to the community. During the last few years, worldwide cities have initiated urban resilience strategies in response to context-specific challenges and identified suitable actions to create innovative solutions (Fastenrath et al., 2019). Governments, public and private partnerships and international institutions have developed resilience strategies for the refurbishment and adaptation of abandoned industrial buildings.

The transformation of obsolete and unused industrial contexts enables to achieve sustainability, functional and technological goals (Rudlin & Falk, 2009). All over the world, industrial infrastructures are converted for new uses, guaranteeing new standards of liveability and contemporary functions to meet society needs. There are lots of case studies that rethink disused industrial plants into contemporary polyfunctional spaces. The FRAC Museum in Dunkerque (2013-2015), the Redfer Warehouse in Sydney (2018), the Gasometers in Wien (1999-2001), the Green Building in Louisville (2008), the Paganini Auditorium in Parma (1999-2001), the Kranspoor in Amsterdam (2007) and the Helbphilarmonie in Hamburg (2007-2017) are some examples of architectural resilience of industrial abandoned warehouses. All these architectures repropose dismissed industrial mills and factories that are renovated and reintroduced in the urban morphological context as active parts of the city system. The building, deprived of its centrality in the urban structure of the city, regains value in contemporary society by complying with functional, physical and public shortcomings useful to the sustainable development of the built environment.
In the scenarios of urban development models, the reuse and conversion of brownfield sites and empty warehouses, as a product of the processes of decentralisation, deindustrialization and obsolescence, become an opportunity to active sustainable regeneration actions. These polices can generate smart innovative strategies for the creation of smart cities. The densification of the suburbs allows to reduce the uncontrolled urban sprawl, enhancing the permeable areas and critical social and building contexts. The transformation processes aimed at the redevelopment of industrial areas are not only based on functional strategies to fill unused spaces, but also rethink the historical and cultural role that these large areas must interpret within the hierarchies of the contemporary city. The industrial building type should not be analysed only from an architectural, compositional and material point of view, but it needs a functional reinterpretation capable of making the shed readable and usable to the community. The old disused factories become, therefore, the basis from which to trigger an evolutionary process that converts metropolises into functional urban identities (Calderazzi, 2015).

2. STATE OF THE ART

2.1 The refurbishment of factories: the catalyst for smart cities urban policies

Today nations are facing relevant challenges related to develop smart economies and improve competitiveness. In this timeframe, refurbishment and valorisation process of the existing building stock, applied to the urban scale, represent and optimal opportunity to redesign peripheries. Recovery actions require, on the one hand, retrofit policies to address the growth of building sector and, on the other hand, strategic adaptation processes of disused and abandoned building clusters in order to increase regeneration beneficial effects that heal social, economic and environmental decay (Davoli et al., 2015). According to Riley and Cotgrave (Riley & Cotgrave, 2011), urban transformation processes can be distinguished in two different building works: new constructions and refurbishment of the existing. In the context of building recovery, they state that refurbishment is a complex topic to generalize, because it includes different meanings. Many authors (Egbu, 1994; Van der Flier & Thomsen, 2005; Douglas, 2006; Juan et al., 2009; Riley & Cotgrave, 2011; Ryu, 2014) identify and define the terms that are most used to classify the different interventions of recovery of disused buildings (Table 2.1-1). The different meanings of these words are attributed exclusively to the ultimate purpose that characterizes each building process. Preservation interventions on buildings with historical values are different from aesthetic maintenance solutions of contemporary buildings or from recovery activities, because it involves the structural parts of a construction.

Terms	*Definition*	*Sources*
Refurbishment	Giving to a building a facelift or a refit to enhance its appearance and function. Extending the useful life of existing building abandoned stock through adaptation processes to update a new version of the original structure.	(Egbu, 1994); (Douglas, 2006); (Juan et al., 2009); (Riley & Cotgrave, 2011); (Ryu, 2014)
Restoration	The work of renewal and repair dilapidated buildings. The recovery process of the existing fabric of a site, reassembling components without the introduction of new materials.	(Brooker & Stone, 2004); (Douglas, 2006); (Scott, 2007); (Riley & Cotgrave, 2011); (Ryu, 2014)
Remodelling	Activities centred on building aesthetic update.	(Douglas, 2006); (Riley & Cotgrave, 2011); (Ryu, 2014)
Retrofit	Fitting new and more modern systems into an existing building.	(Riley & Cotgrave, 2011); (Ryu, 2014)
Conversion	Alteration of building functions while the main structure remains unchanged.	(Riley & Cotgrave, 2011); (Ryu, 2014)
Adaptation	Any intervention to adjust, repair, reuse, upgrade a building to suit new conditions or requirements. Construction works that allow changes of functions, perfor-	(Aplin, 2002); (Douglas, 2006); (Plevoets, 2014)

	mances and capacity. Making flexible and reversible changes. Adapting an historic building to new functions, preserving its past and sense of place.	
Preservation	Intervention that maintains unaltered the building structure by slowing down its obsolescence. Keeping the building alive even though are present damaged parts, saving its heritage value.	(Aplin, 2002); (Brooker & Stone, 2004); (Scott, 2007)
Conservation	Interventions scenarios that analyses historic context, retaining its cultural significance. A process that takes care to environmental and architectural significance of an iconic place.	(Aplin, 2002); (Boito, 1893)
Renovation	The transformation process of the physical, functional, financial, architectural and ecological characteristics of a building to realize a comprehensive and useful extension of the lifespan.	(Van der Flier & Thomsen, 2005); (Douglas, 2006)

Table 2.1-1 Classification and definitions of terms used in building regeneration processes.

The refurbishment of unused warehouses is fast becoming an important sector in the construction industry due to the change in economic conditions and the emphasis on sustainable development (Kohler & Hassler, 2002; Riley & Cotgrave, 2011). These interventions are characterised by a high level of complexity (Egbu, 1997; Rahmat, 2008; Ali, 2010) and need a greater attention on the management and active control of all stages of adaptation, trying to prevent risks. At the same time, the quality of design information in refurbishment projects is a fundamental feature to reduce uncertainties (Mokariantabari et al., 2019). In fact, it is difficult to decide the best economically and structurally feasible strategy to apply on existent building stock (Noori & Mokariantabari, 2019). Uncertainties arise when changes are unavoidable in building refurbishment and organizations aren't able to interpret optimally the information (Ofori, 2013). Ali (Ali, 2010) states that briefing is one of the most important sources for designer in recovery processes, because it is possible to capture client's needs, social problems and lacks, deciding which can be the most practicable scenarios.

The issues of building redevelopment concern renovation and securing actions of abandoned industrial stock, both functional and physical, to dissipate less embedded energy and use natural sources (Morano et al., 2020). According to Papadopoulos et al. (Papadopoulos et al.; 2002), Gorgolewski (Gorgolewski; 1995) and Hong et al. (Hong et al.; 2006) energy efficient refurbishment activities, considered for the recovery of existing buildings, reduce energy consumption and improve thermal indoor comfort and optimal environmental conditions. In addition, the goal number 11 of 2030 Agenda for Sustainable Development ("Make cities and human settlements inclusive, safe, resilient and sustainable") (United Nations Development Programme, 2015) states that refurbishment actions in the urban environment achieve a better liveability level of metropolis. Considering climate change problems, the implementation in building conversion intervention of energy performance technologies plays a significant role to perceive sustainability goals, reducing pollution (gas and CO_2 emissions), developing renewable sources and expanding local economies (Mickaityte, 2008; Thomas et al., 2014; Conejos, 2012 ; Davoli et al., 2015; Akande et al., 2016; Corrado & Ballarini, 2016). Sunikka (Sunikka, 2003) concludes that the real potential for sustainable building and CO_2 reduction lies in a correct and efficient management of the existent stock of abandoned buildings.

Keeping and Shiers (Keeping & Shiers, 1996) synthesize the benefits of green refurbishment processes in three main points:

1) Recovery interventions reduce energy costs through the adoption of simpler heating and power installations;
2) Building transformation with retrofitting actions reduces maintenance costs due to the design of accessible spaces and efficient technologies, cheaper to repair;
3) The reuse of existing building stock and high spaces liveability decrease absenteeism.

Sitar et al. (Sitar et al., 2006) identify four sustainable refurbishment principles strictly related to technical and ecological aspects of building life cycle:

A) Improvement of living conditions and spaces flexibility to host multiple functions;
B) Decreasing of energy use and optimal management of non-renewable resources. This principle is linked with the application of smart technologies that can monitor building energy consumption;
C) Application of environment-friendly materials and renewable sources;
D) Innovative design planning of abandoned areas, considering people needs and respecting rules and surroundings.

The recovery of abandoned factories is strictly connected to urban sustainable development. According to Sobotka and Wyatt (Sobotka & Wyatt, 1998), the rules of sustainable development must refer to building life cycle stages, taking into account dismantling activities and reusing materials to assess volume shape transformations and activating refurbishment processes to increase spaces usability over time. At the same time, to perceive the creation of smart cities, every level of government (Local, Regional, National and European) has the responsibility to hypothesize innovative policies in the field of preservation, reuse, gentrification, tourism and natural environment. These rules must be improved and coordinated by Member States to achieve a new sense of responsibility by communities (European Union, 2007). Urban programmes have to involve citizens in the conversion processes of unused brownfields, because social inclusion and participation open a contemporary vision of the city, much more “human”. Designing more efficient district through the rehabilitation of the existing built resources ensures the possibility to promote constructive solutions complying green buildings and sustainable construction requirements.

The Italian project “Ecoquartieri per l’Italia”, developed by Legambiente, the Green Building Council of Italy and Audis (Dismissed Urban Area Association), includes innovative sustainable strategies of urban administration in relation to energy, climate and smart cities topics. The eco-district programme represents a different approach to modify the territory in order to achieve high quality of living and optimize the use of natural resources, sustainable materials and empty spaces (Davoli et al., 2015). The idea of transforming neighbourhoods, starting from peripheral areas, allows to activate sustainable processes for the development of smart cities, aiming to address suburbs’ issues, as well as the degraded and abandoned historic districts, with a vision that consider building refurbishment interventions and urban environment aspects simultaneously.

Ance Institute (Ance, 2013) identifies three different types of eco-district, based on different type of interventions on urban environment:

a) New neighbourhood with modern buildings characterised by new construction and functions, without considering the existing. This first scenario is typical of the expansionist process of recent years, where it is preferred to build new high-tech volumes, without taking into account the potentials that empty volumes and user-free spaces can offer;
b) Refurbishment of existing empty areas into new services for the community. This solution is applied when there is a high presence of disused areas that can be reassessed as important nodes for the realization of future cities;
c) Historic district with a high level of architectural quality. In this situation smart interventions of recovery, restoration and conservative behaviours are the

most suitable scenarios of intervention to preserve architectural values and spaces iconicity and memory.

These land use strategies and, in particular, the recovery of marginally abandoned areas, allow the implementation of policies aimed at the creation of sustainable and technologically advanced cities. The term “smart city” regards the implementation of user-friendly information and communication technologies and strategies aimed at urban regeneration and automation. This modern city concept is an avant-garde, progressive and resource-efficient scenarios that provides, at the same time, a high quality of life and promotes social inclusion and disused buildings requalification. The structure of the sustainable city connects the urban transport apparatus with building and services of the metropolitan area, with the aim of creating disparate and effective road networks, favouring slow mobility and the use of public transport such as the metro, buses and sharing services. The technological apparatus and security systems, implemented in the concept of a sustainable city, facilitate the use of internet or applications for smartphones and PCs to users and increase the level of management and control of public spaces. The city enters, therefore, in the digital and innovation world, becoming not only a place to live, but where to establish virtual and remote relationships, always remaining connected on events of the everyday life. Smart cities forcefully tackle the current global challenges, such as climate change and scarcity of resources, trying to find sustainable ways to reduce impacts of society. Figure 2.1-1 (Figure 2.1-1) shows the components involved in the development of smart sustainable cities. The implementation of land-use development policies through the inclusion of components necessary for the development of smart cities allows to build resilient spaces in the sense that urban systems are made more resistant and adaptable to influences from inside and outside.

With a view to the refurbishment of disused industrial constructions, sustainable architecture projects limit the environmental impact with the aim of increasing energy efficiency, improving indoor and outdoor comfort conditions and physically and socially reconnecting the neighbourhoods of modern metropolises (Vizzarri, 2017). An innovative model for the functional, structural and compositional recovery of dismissed warehouses that can transform marginal urban contexts and develop policies and strategies aimed at creating smart cities is defined as "adaptive reuse".

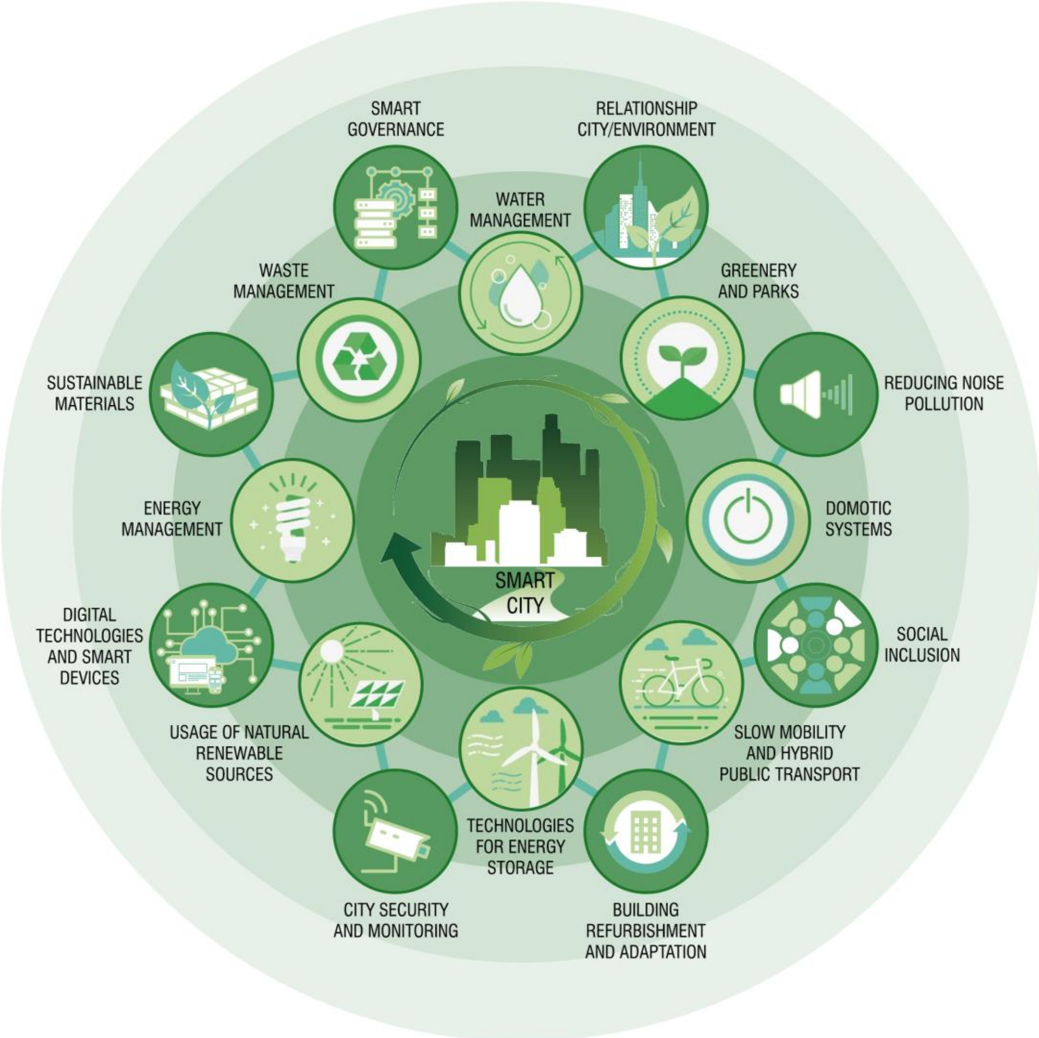


Figure 2.1-1 Components involved in the development of smart sustainable cities.

2.2 Adaptive reuse as a strategy towards sustainable development

The conversion of city empty spaces no longer by expanding its boundaries, but by working within them, in a process of self-regeneration with strong cultural and social motivations, necessitates of strategic refurbishment policies and opens up important reflections on the enhancement of history, architecture, landscape restoration and conservation measures (Piludu, 2017).

Building conversion and rehabilitation are linked to sustainability issues, and the realization of efficient reuse interventions on abandoned industrial sites can reduce the adverse effects on the environment and gas emissions (UNEP, 2006). Sustainability refers to the meeting of needs of the present without compromising the ability of future generations to meet their own needs (WCED, 1987) or can be defined as the processes of using, conserving and enhancing the community's resources to increase the quality of life and maintain ecological policies (Commonwealth of Australia, 1992). The Brundtland Report (WCED, 1987) introduces the theme of sustainable development, defining it as a strategy to optimise the relationship between the global society and its natural environment, considering social, economic and environmental goals of society. This term is linked with economic development and environmental protection and emphasizes the role of modern cities to ensure the satisfaction of contemporary and future society needs (Nocca, 2017). Adaptation actions are accounted as environmentally sustainable interventions on abandoned buildings, because they involve less material use, less transport, less energy consumption and less pollution and waste during recovery phases (Johnstone, 1995; Bullen, 2007). The design strategies of conversion of derelict volumes, in terms of sustainability and circular economy, are becoming a requirement in contemporary cities to assess environmental issues (Kilbert, 2007; Lacy & Rutqvist, 2016; Pomponi & Moncaster, 2017).

Nowadays, the topic of sustainable development is considered by all the countries and institutions who want to achieve a balance between social, environmental and economic spheres as a fundamental objective for developing future avant-garde and creative design actions that utilize energy, technologies and smart materials efficiently in order to satisfy population needs (Othman & Elsaay, 2018). In particular, the challenge of recovering and converting dismissed urban contexts must relate with the seventeen goals of the Urban Agenda 2030 for Sustainable Development (United Nations Development Programme, 2015) (Figure 2.2-1) for delivering feasible planning strategies that enhance society life quality, modern infrastructures, services and innovative solutions to use renewable resources, preserving the natural environment, promoting inclusion, reducing gas emissions and overcoming the fragmentation of urban policies. All these points can be transmuted in communities' actions and collaborations to implement contemporary options for improving a better and liveable world. Physical, functional and technological refurbishment of unused built sites narrows the gaps between reality and expectations, making human settlements inclusive, safe, resilient and sustainable.

Figure 2.2-1 Goals of the 2030 Urban Agenda for Sustainable Development (United Nations Development Programme, 2015).

Reusing decommissioned industrial areas as a result of decentralization, deindustrialization and obsolescence, becomes an opportunity to set in motion processes of regeneration of places that incorporate architectural values in terms of identity and recognisability. The idea to recover brownfields and derelict factories is based on the

need to transform peripheries, giving new dignity to these derelict and unused areas. The regeneration of an industrial building not only retains its aesthetic features, but also implies an act of repurposing that can make the building useful to the community and active in the city dynamic system. Old and decommissioned factories can be accounted as available spaces to organize smart processes that hypothesise new services in the existing building stock and control urban sprawl. A derelict industrial site isn't considered as an empty place but as a potential flexible context to satisfy community basic needs and in which architects can insert attractive services and adopt iconic shapes to develop tourism policies in the city periphery. Urban regeneration processes involve socioeconomic, environmental, technical, and ethical perspectives, which are strictly interconnected to each other. In the context of urban transformation, the reuse of derelict and abandoned industrial sites becomes an opportunity to bring life to sustainable and avant-garde redevelopment processes of abandoned sites, incorporating iconic characteristics and recognisability (Calderazzi, 2015).
Adaptive reuse models allow to manage the abandoned anthropized territory, providing effective solutions, activating urban regeneration policies. The procedure takes into account obsolete and abandoned sites, restoring them and changing their use (Bullen, 2007; Langston et al., 2008). Disused factories and industrial warehouses are the principal components to trigger virtuous processes of building recovery in urban suburbs, trying to control and manage urban sprawl of modern cities. Planning policies and land-use conversion, with the help of recovery actions of abandoned peripheral industrial fabrics, open the doors to a modern consideration of the metropolis, where the periphery and the old town are related to each other through the introduction of spaces, functions and services to meet the needs of the community. The transformation of obsolete industrial sheds, considering adaptive reuse strategies, enables to achieve sustainability, functional and technological goals (Kohler, 1999; Latham, 2000; Rudlin & Falk, 2009). This type of renewal strategy brings new life to disused or under-utilised assets. The process increases space likeability and social benefit by creating sites that satisfy community needs and re-engage people to use them, hosting new services, connected with the old city structure and touristic places.

Adaptive reuse can be applied by professional figures who wants to show to contemporary generations the power of the industrial past and dares to imagine a future for its legacy (Robiglio, 2017). It seems to be an increasingly promising strategy for converting abandoned buildings. Adaptive reuse, nowadays, can be accounted as a sustainable strategy that promotes the development of urban planning and structures processes of revitalization of abandoned areas, creating a resilient architecture. It is an effective strategy to optimize building performances and increase urban quality (Bullen & Love, 2011a). Adaptive reuse models conserve the architectural, social, cultural and structural values (Latham, 2000). This modern approach can transform abandoned warehouses into accessible, flexible, functional and useable places as well as provide the added benefit of regenerating an area in a sustainable manner (Bullen & Love, 2011c). In addition, decisions on the allocation of resources for building adaptation are based on a set of multiple, often conflicting, criteria, as well as on the preferences of various stakeholders who attribute different importance to the recovery interventions with adaptive reuse techniques (Bottero et al., 2019). However, it's possible to identify different approaches to adaptive reuse and different recovery policies. Elsorady (Elsorady, 2014) lists the principles to consider in adaptive reuse interventions. They can be synthesized in four main definitions: adaptation allows to preserve the existent structure, with minimal changes on it, inserting contemporary functions that satisfy population needs; conversion processes respect the sustainability principles that help to the design with adaptive reuse features; community engagement is fundamental to active participative design activities; the selection of potential adaptive uses and smart policies can be consider as viable options to develop land regeneration interventions. Disused areas represent an opportunity, but also a challenge: reassigning a new identity to abandoned marginal buildings by reintroducing them as elements and active places of the city (Calderazzi, 2012).
Lots of authors conduct studies on the topic of adaptive reuse, paying the attention on potentials and on opportunities that building adaptation guarantees to assess sustainable development (Bon & Hutchinson, 2000; Ball, 2002; Gallant & Blickle, 2005). Professionals and practitioners consider adaptive reuse an optimal solution respect new

construction in terms of sustainability, energy efficiency and Life Cycle Assessment (LCA)(Douglas, 2006; Langston, 2008; Conejos & Langston, 2015). A correct development of adaptive reuse models can improve financial, environmental, social and technological performance of existing sheds. The importance of this trend is that adaptation extend useful life of abandoned sites stock by making them more durable and useful for urban improvement (Lowe, 2004; Larsson, 2004). Extending facilities operational life, structures can react efficiently to external and internal agents as climate change, indoor quality and weather (Love & Bullen, 2009). The reuse of contaminated industries is considered by Paccagnan and Turvani (Paccagnan & Turvani, 2007) as an optimal way to reduce land demand and boost economic development. Even with a higher initial cost, related to recovery and reclamation actions on existing structures, adaptive reuse, applied on derelict sites, amortizes the initial costs of refurbishment. This happens because the building itself begins to be alive and used, having different functions (Olivadese, 2014). According to Kirovovà and Sigmundovà (Kirovovà & Sigmundovà, 2014), it's necessary to identify and classify sustainability principles for adaptive reuse that reintegrate former industrial sites into the socio-economic and urban structure. Eray et al. (Eray et al., 2019) consider building adaptation processes more complex respect green-field construction projects. This modern approach, in fact, requires the management of different stages, multiple stakeholders and planning methods in order to secure the success of the applied strategy. The processes of recovery in relation to renovation management of design stages are diverse and dynamic, because multiple criteria have to be taken into account (Conejos et al., 2014; Conejos et al., 2017). The successful reuse of abandoned industrial sites requires a deepened analysis to understand how the layers, the functions, the transformation activities and all the subsystems are interconnected with and influence each other (DEH, 2004; Alikhani, 2009).

Giving a new identity to abandoned industrial sheds serves to reintegrate and readapt these vast areas in the metropolis system without lose the architectural values that have characterized their previous industrial and productive use. Many underutilized factories are viewed as the starting point for city regeneration and play a crucial role in the social, economic and cultural development of society. In addition, there is a strong awareness between stakeholders perception that is cheaper to convert abandoned sites rather than to demolish and realize new ones (Vanegas et al., 1995; Ball, 2002; Gregory, 2004; DEH, 2004; Pearce, 2004; Douglas, 2006). This consciousness of building adaptation potentials promotes professionals interest in adaptive reuse strategies and, at the same time, amplify the studies regarding the parameters that should be considered in the refurbishment process or that can affect building conversions (Ball, 2002; Pearce et al., 2004; Aigwi et al., 2018). The adaptive reuse model not only retains the physical built asset but also enables it to be used in a feasible and effective way that can service the changing needs of stakeholders. Adaptive reuse offers a more viable and smart process of dealing with buildings than demolition. This model addresses issues of conservation and preservation of abandoned volumes, as well as strategies and policies to manage these type of approaches (Mohamed & Alauddin K, 2016).

2.3 Definitions of adaptive reuse

Adaptive reuse models usually refer to the use of abandoned, disused, derelict and contaminated sites for multiple strategic purposes other than those originally intended or designed for (Mohamed & Alauddin, 2016). According to Enache (Enache, 2014), adaptive reuse of empty volumes and spaces is a fundamental practise in order to maintain existing buildings, by changing its purpose, after that structural features have reached their level of maturity in the life cycle process. Adaptive reuse approaches allow to amplify materials durability and decrease carbon footprints. The term is also related to issues of conservation and preservation of built assets through the implementation of effective strategies and policies that consider architectural building heritage values. Lots of authors define the term “Adaptive Reuse”.
Fitch (Fitch, 1990) defines adaptive reuse as “the only economic way in which old buildings can be saved, by adapting them to the requirements of new tenants, reorganising internal spaces to host modern functions”.

The term adaptive reuse, few years later, is explained by Dolnick and Davidson (Dolnick & Davidson, 1999) as the rehabilitation and renovation processes of existing buildings or structures for any users different by the present one.
Latham (Latham, 2000) considers this modern approach as a "process that retains as much as possible of the original building while upgrading the performance to suit modern standards and changing user requirements".
The most utilized and known definition of "Adaptive Reuse" is given by the Australian Department of the Environment and Heritage. This institution resumes the term adaptive reuse as "a process that changes a disused or ineffective item into a new item that can be used for a different purpose" (DEH,2004).
Douglas considers previously the two words separately. The term "Adaptation" is derived from the Latin word "ad" (to) plus "aptar" (fit). "Reuse" refers to a "change of use" in building conversion processes. In a second time, the author defines adaptive reuse as "the conversion of a building to undertake a modified change of use required by new or existing owners" (Douglas, 2006).
Other definitions of adaptive reuse are stated by Bullen (Bullen, 2007), Wilkinson and Reed (Wilkinson & Reed, 2008), Mofidi Shemirani et al. (Mofidi Shemirani et al., 2008), Love and Bullen (Love & Bullen, 2009) and Vardopoulos and Theodoropoulou (Vardopoulos & Theodoropoulou, 2018).

Respectively the term adaptive reuse is explained by these authors as:

A) Rehabilitation, renovation or restoration work that does not necessarily involve a change of use, but that can extend the useful life and sustainability in a combination of improvement and conversion;
B) Activity in maintaining as much of the original as possible, improving performance with modern standards and considering changing society needs;
C) Rehabilitation or renovation of existing buildings or structures for any uses different from the present uses;
D) Any adjustment that can respond to anticipated or actual consequences associated with climate change;

E) An industrial building conversion process to undertake a change of use, retaining as much as possible of the original construction, while upgrading the performance to meet current standards.

These definitions regarding the concept of adaptive reuse focus on activities closely related to the issues of recovery, restoration and redevelopment of unused empty volumes, with the emphasis on the building's ability to host new functions and on its functional adaptation.
Considering the urban regeneration activities of disused industrial sites, the term "Adaptive Reuse" can be defined as “the process that transforms a disused industrial site, historical and not, into a new functional organism able to meet the needs of the population, without, at the same time, affecting its formal architectural values”. Adaptive reuse processes convert an outdated and abandoned building into a new and technological functional envelope that increases life quality in contemporary cities (Figure 2.3-1).

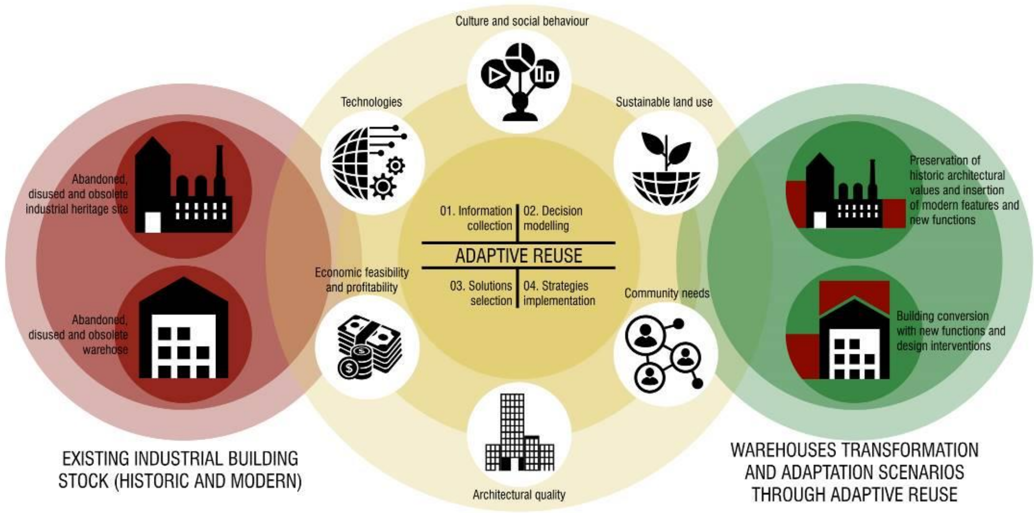


Figure 2.3-1 Schematic graph to define adaptive reuse approaches.

2.4 The adaptive reuse of industrial heritage

In the second half of the twentieth century the recycling of derelict and contaminated historic industrial areas becomes an indispensable approach to develop sustainability strategies. From the 1980s until today, the regeneration and reclamation processes of brownfields, former industrial sites and historic sheds are considered as a prevalent topic for the implementation of urban development action in Europe, Asia and North America (Plevoets & Van Cleempoel, 2019). This period changes developer's perception of cities, focusing the attention on industrial heritage and abandoned structures to perceive economic profit, attraction marginal polyfunctional poles and new urban landmarks (Rodopoulou, 2017). The knowledge on the preservation techniques of industrial heritage sites which are no more capable to guarantee their efficiency in the contemporary world is important to choose right intervention scenarios in relation to community actual needs. The new concept of conservation accounts the need to preserve buildings as documents of social history and as evidence of the way of life of those labelled ordinary people, rather than applying these interventions just for their architectural quality and historic architectural interest (Pearce, 1989).
Tanghe et al. (Tanghe et al., 1984) in their researches explain this new trend as an optimal solution to shift from urban sprawl policies to urban planning strategies that could redevelop derelict areas and structures within the city. The transformation of derelict heritage sites can be a vehicle to start regeneration policies (Pendlebury, 2002; Strange & Whitney, 2003; Orbasli, 2008). Heritage industrial buildings are the symbol of industrial revolution and incorporate cultural values and memories.

Pickard (Pickard, 1996) asserts that sustainable historic conservation processes with the application of adaptive reuse approaches should:

a) Reflect local society and traditions;
b) Improve and transform community quality of life;
c) Maintain local identity, vitality and diversity, strengthening social inclusion;

d) Decrease the depletion of non-renewal architectural assets;
e) Develop collective responsibility behaviours to preserve and use heritage buildings;
f) Empower community involvement and participation;
g) Provide policies framework to link iconic architecture with contemporary building features.

Historic industrial buildings are not only considered as large unused spaces, but also represent the evolution of a city. These buildings incorporate the culture, society and history of a place, helping future generations to understand urban cities past (Merlino, 2018). They can affect community well-being (Bullen & Love, 2011c). Moreover, the preservation of old factories is a priority action aimed at the maintenance of these historic architectures to future generations (Langston, 2012). At the same time, the majority of old buildings require amount of adaptation and renovation activities before return to its functional viability (Bond, 2011).
The application of adaptive reuse processes on abandoned and unused historic industrial buildings connects the historical and architectural value of a building with the current community, characterizing spaces and volumes with new uses. Concerning the reuse policies for converting heritage factories, building adaptation measures are not limited simply to changes of destination or compliance with the regulatory framework, but imply a redefinition of spatial and formal construction qualities that have an impact on its new urban role (Zanetti, 2012).
Sometimes, developers and architects don't see the architectural values and potentials of reconversion in heritage buildings (Alfrey & Putnam, 1992). While in most worldwide countries, warehouses, stores and factories are protected by heritage legislation, in others the same construction typology aren't taken into account for reuse purposes (Louw, 2016). Where adaptive reuse strategies are not applied to modify building structure and functions, only external skin and facades are retained to make redevelopment procedures as easy as possible, without giving the correct importance to the whole project transformation.

Adaptive reuse is the process that allows to redesign a property to a state of utility in the urban tissue, through repair or alteration activities, which makes possible and efficient contemporary uses in order to preserve iconic building features from an historic, architectural and cultural point of view (Petzet, 2009). Nowadays, the adaptive reuse of industrial buildings represents a genuine challenge for professional figures, like architects, engineers and designers, in search of innovative solutions for towns development. In fact, these empty and vast spaces are considered liabilities for surrounding areas, but, lots of them are converted into modern entities to assess urban quality of life. In addition to the process of refurbishment of abandoned industrial facilities, functions, construction techniques, technologies and material are studied by architects and engineers to reconfigure building assets (Loures & Panagopoulos, 2008). Sometimes the contemporary use of a historic brownfield requires new formal and design additions, which should have minimal impact on its heritage architectural significance and on its setting (Byard, 1998). Differently from the past, professionals understand the importance of reusing these resources, performing firstly reclamation works and achieving multi-functionality of spaces with attention to historic, socio-economic and cultural aspects (Luis & Panagopoulos, 2007). A strategic reuse of abandoned industrial heritage factories creates favourable conditions in terms of economic growth, control of city expansion, land-use management and urban densification and social cohesion (Moore, 2002). In addition, interventions on historic brownfields can be considered as an intergenerational dialogue between professionals and these debates can be complex and in constant evolution (Scott, 2007). Therefore, it is necessary to find a balanced solution by comparing the past, connected with industrial revolution era, and the present, composed by a multiplicity of existing buildings and contemporary design creations and technological alternatives, always considering policies and regulations (Benassi, 2013).
With adaptive reuse approaches, an old warehouse would no longer be considered as an empty sculpture, but as an active product of a whole socio-economic system (Cantacuzino, 1989). At the same time, the conservation of industrial built heritage necessitates of building classification procedures to control building obsolescence.

Loures and Panagopoulos (Loures & Panagopoulos, 2008) consider reconversion scenarios of heritage sheds as a significant strategy to increase life quality and land use, modifying obsolete relict in new cultural and environmental places. The conservation and adaptation of architectural industrial values may increase the significance of the refurbishment intervention in relation to local landscape characteristics (Wang & Zeng, 2010). Clark (Clark, 2013) states the connection between industrial heritage and economic, architectural and technical achievements, structure and materials production and recycle. Yung and Chan (Yung & Chan, 2012) point out that adaptive reuse models can merge the aesthetic architectural features of heritage buildings with functions satisfying social useful purpose and finding an effective approach for self-financing and to achieve sustainable conservation. According to Roido et al. (Roido et al., 2013), the application of adaptive reuse approaches on industrial old sites guarantees not only the preservation of city's identity but also increase economy and tourism. Adaptive reuse is considered by authors the only way to save, in an economic manner, heritage sites and aesthetical values of historic warehouses. However, to preserve during time building performances and usage, regular care and maintenance are required (Plevoets & Van Cleempoel, 2011).
In the context of industrial heritage adaptive reuse methods contribute to regenerate historic brownfields and warehouses, retaining their historical/archaeological, aesthetic/cultural, economic/sustainable, functional/spatial and social/psychological values (Latham, 2000). The recycling of historic brownfields is an essential procedure for smart cities development (Fouad et al., 2014). The contemporary practises in adaptive reuse processes are focused on different aspects regarding sustainability, authenticity, integrity preservation, without compromising architectural features and applying minimum intervention and energy efficiency actions.
Considering the preservation aspects of industrial buildings, the theme of values authentication requires a deep research in relation to heritage. Authenticity item is defined as an essential qualitative factor that can evaluate the credibility of available icon sources and measure the heritage degree and buildings importance (The Riga Charter on Authenticity and Historical Reconstruction in Relationship to Cultural Heritage,

2000), considering creativity, truth and cultural tradition (Jokilehto, 2006). The architectural and historic essence of heritage structures lays in the recognition of tangible and intangible aspects of authenticity. A big challenge for architects is preserving building authenticity.

Mengusoglu and Boyacioglu (Mengusoglu & Boyacioglu, 2013) highlight four different principles for the evaluation of abandoned heritage industrial warehouses:

1) Functional integrity is the most relevant feature for the analysis of industrial heritage. It provides accurate analysis to understand the historical processes and building evolution, with the aim to plan and manage its modern-day use. The largest interventions of adaptation on heritage factories allow to implement virtuous and original new design purposes;
2) Structural integrity is taking into account to define the current physical condition of buildings through the relation between survived architectural elements and the analysis of previous functions. In order to preserve structural values, the adaptive reuse intervention should be reversible with a minimum loss in existing materials and clearly separating the new from the old (Worthing & Bond, 2008);
3) Aesthetic integrity manages the relations among the individual formal elements to describe the main features of heritage volumes. Each industrial historic site can be analysed in terms of volumes, surfaces, components and shapes to understand if it is characterized by aesthetic value or not.
4) Technological functionalism can be described as a crucial factor for the development of architectural smart solutions (Rogic, 2009). It is a principle strictly related to aesthetic integrity of heritage buildings and regards the compatibility of the industrial historic factory to insert technologies, energy efficient systems and smart modern solutions in its spaces, without compromising the archaeological iconicity.

The gradual acknowledgement between stakeholders that the culture of refurbishment and conservation can play a catalytic role in urban regeneration actions has changed the perception towards the use of abandoned industrial built heritage (Mengusoglu & Boyacioglu, 2013). As a result of the increasing competition between metropolis at the global scale, industrial cities try to give importance to typological uniqueness of warehouses and establish a specific place identity to attract investment, tourists and residents. Industrial heritage recovery and restoration policies are widely used to promote distinctive representations of a place, especially in industrial peripheral contexts. In consequence, building industrial heritage has become a valuable asset to be used to regenerate declining urban areas and promote a more desirable and futuristic place image, assessing spaces life quality. Current urban policies for urban sustainable regeneration strongly support the concept of recovering and reusing these iconic buildings to create more accessible, high quality, mixed use, high-density and technological neighbourhoods.

The most successful historic industrial sites conversions through adaptive reuse model are those that best respect and retain the building's iconic values and add a contemporary layer that gives a modern appearance to reused areas (DEH, 2004). Successful designs depend on a close understanding of factories main characteristics and potentials and sensitivity to both scale and detail (Benassi, 2013).

2.4.1 Drivers and barriers of adaptive reuse

Adaptive reuse processes play a fundamental role in urban regeneration activities in suburbs. This type of approach not only guarantees the reuse of spaces that have become obsolete and abandoned over time, but also allows to pursue sustainable development and economic growth objectives (Myers & Wyatt, 2004), making existing structures usable by the community. Political, economic, social, physical, technological, functional and legal factors influence building conversion scenarios, as well as make the processes of choosing optimal strategies for the reuse of disused buildings much more complex. Establishing the viability of adaptive reuse as a feasible option to reduce urban sprawl, it is important to understand drivers and barriers related to these approaches. A large number of drivers promotes the growth of adaptive reuse. They are linked with cost-effectiveness, spatial, sustainable and technological efficiency features. Nowadays, clients opt to recovery and convert an obsolete existing building due to the rise of energy and construction costs (Douglas, 2006; Kohler & Yang, 2007) like materials, transports and resources. According to Ellison et al. (Ellison et al., 2007) the rising energy prices change the decisions of property investors towards the improvement of energy efficiency buildings to increase market demand. In addition, the significant growth of the construction sector during last decades increase the number of buildings available for refurbishment processes (Shah & Kumar, 2005). Adaptive reuse strategies often transform the interior design of spaces. Readapting an empty surface to host new functions is a more effective solution respect relocation, especially because building adaptation does not affect structural parts (Van der Voordt, 2004).

The success of adaptive reuse interventions depends on the adaptability and flexibility of building's interior spaces. Large surfaces guarantee a better and simple functional reuse activity, as well as lower construction costs, since they are easily manageable, modular and adaptable to new needs, ensuring high indoor comfort over time with technological and sustainable smart devices and solutions (Bullen & Love, 2011b). At the same time, the refurbishment and transformation of buildings with low space flexibility require higher renovation costs to meet the new spatial needs linked with the functional program that the structures must incorporate (Ellison et al., 2007).

Adaptive reuse solutions improve the aesthetic appearance of buildings, not neglecting the aspects of energy and sustainable efficiency and the façade technologies to be adopted (Adair et al., 2003; De Valence, 2015). In addition, building adaptation interventions reduce the visual impact due to poor building quality or high façade obsolescence (Yau et al., 2008). Similar strategies represent solid opportunities to give buildings a new and modern identity, optimizing lifecycle costs (Shah & Kumar, 2005). The increase in the recovery of disused buildings is not only linked to physical and degradation aspects, but also to the changing expectations of users (Kohler &

Yang, 2007). In order to meet the new needs of the population, building conversion measures must comply with society's demands. In the context that people expectations are not met by the functions included in the reused buildings, unsatisfactory conditions of occupants can be verified (Ellison & Sayce, 2007).
The implementation of energy systems, plants and performing façade technologies significantly reduce energy waste, use renewable sources and increase users cost savings (Brown, 2006; Bruhns et al., 2006).
Building life expectancy is another parameter to consider before the application of adaptive reuse processes (De Silva & Perera, 2016). It determines the possibility to reuse an empty structure rather than demolition process (Bradley & Kohler, 2007). As stated by Kendall (Kendall, 1999), extending building lifecycle requires an accurate study of structural, material, functional and spatial assets to evaluate the construction potentials of reuse and the possibility to accommodate modern technologies. A disused volume can be adapted if incorporates grate flexibility, space efficiencies and market demands (Ellison et al., 2007). A high market demand is linked to investors confidence in long-term investment and profitability of services. In addition, building life cycle must consider future maintenance and operating costs. A high level of materials, components and structures decay may require great refurbishment interventions with problematic estimation of service and physical life and the increase of future recovery costs (Lutzkendorf & Lorenz, 2005).
From a political point of view, government agencies are the first candidates to improve adaptive reuse policies to develop regeneration plans and apply a strategic overview to select the most feasible construction to be reused. Barber (Barber, 2003) and Shipley et al. (Shipley et al., 2006) states that institution favourites the development of refurbishment policies, especially for heritage sites, through financial incentives. The introduction of economic incentives provides income and property tax reductions, offering more flexibility to planning requirements and helping to mitigate urban decay (Langston et al. 2008).
Encouraging the population towards the adoption of building reuse interventions involves a number of steps that include: the choice of site; the analysis of the municipal

and regional building regulations; the activities of site expropriation for recovery interventions; obtaining funds and incentives for its implementation and permissions to intervene and transform the selected area.
Although the benefits of adaptive reuse on the development of the existing urban fabric are multiple, there are many negative factors that can compromise the feasibility of building recovery. The complexity of the intervention associated with the reuse and transformation of derelict and abandoned buildings into new functions is one of the major barriers that affect adaptation projects (Kurul, 2007). This happens because old buildings aren't flexible enough to guarantee modern services, plants and technologies. Very often the presence of very small spaces makes the accessibility to the interiors difficult and, consequently, the design of effective escape routes, not ensuring the safety and usability of places by all people. Other barriers include people unfamiliarity with older materials, the necessity of detailed structural evaluation, monitoring, diagnosis and planning of building components and construction level of decay (Bullen & Love, 2011b).
In relation to this final issue, heritage building fabric, in some cases, may have a high level of deterioration that necessitates of special maintenance and repair actions. These causes an exponential rise of recovery costs. The presence of columns and internal partition walls make the current layout of a historic building inappropriate for any change of use. These types of structures are not flexible enough to host new functions, because are characterised by poor space quality (Remoy & Van der Voordt, 2007).
Countries building codes, regulations, conservation guidelines, licensing and planning requirements establish rules and parameters for the application of conversion processes to bring older facilities up to current performance level (Cooper, 2001). At the same time, these limit choices of intervention impeding adaptive reuse transformation solutions, because they may take too extensive modifications and expensive resources. In addition, modifying buildings classification through building adaptation approaches involve zoning changes and compliance with contemporary building codes (Langston et al., 2008). This restricts possible scenarios and amplifies com-

plexity for designers to find appropriate solutions, in particular for heritage sites. Considering the economic sphere, contractors are contrary to renovate old buildings, because adaptive reuse intervention can be risky, lengthy and decrease profits (Reyers & Mansfield, 2001). In addition, a lack of information, project drawings and the discovery of problems, materials defections and dimensional inconsistences can stymie adaptive reuse approaches (Remoy & Van der Voordt, 2007).

Figure 2.4.1-1 (Figure 2.4.1-1) resumes the main drivers and barriers that influence building adaptive reuse interventions arisen by the literature review process. In particular, the scheme highlights how the presence or not of strengths and weaknesses can affect the design choices of stakeholders. If the environmental impact, due to the presence of several negative factors, is high, the design and strategic decisions are more directed towards recovery and restoration activities. At the same time, if there are favourable physical, spatial, environmental and economic assumptions, it is advisable to intervene on abandoned and empty volumes through adaptive reuse activities and urban regeneration interventions.

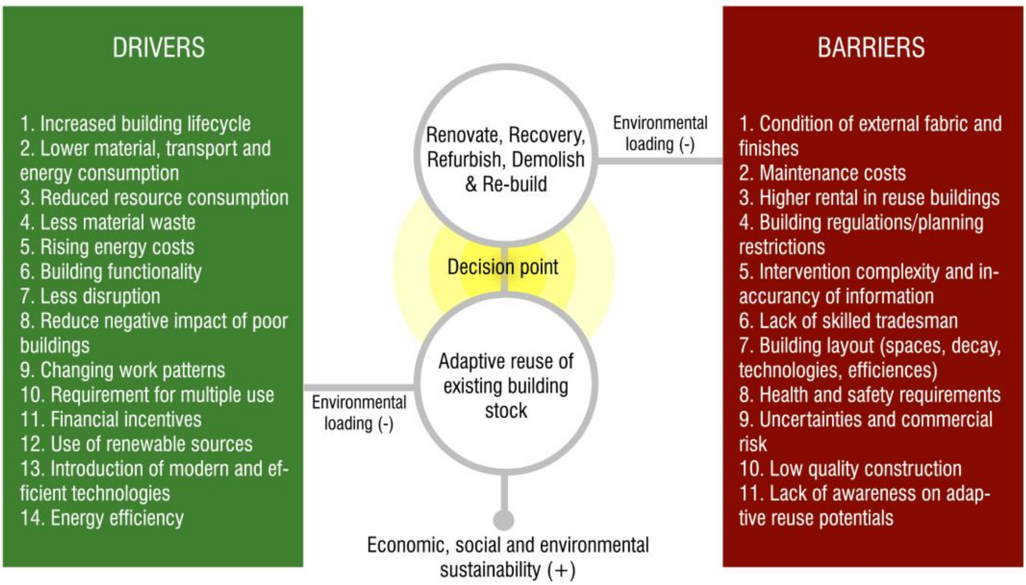


Figure 2.4.1-1 Drivers and barriers of adaptive reuse approaches (Alikhani, 2009; Bullen & Love, 2011a; b).

Building's adaptive reuse strategies reduce waste, whole life costs and lead to the development of building functional, spatial and architectural conversion. On the contrary, derelict and old structures low operational performances decrease the expectations of owners and occupiers. Building recovery and conversion strategies very often have to deal with new market trends and adapt to changing population needs. In recent years, functional, economic, social and environmental sustainability benefits of adaptive reuse receive widespread attention by stakeholders to activate smart regeneration processes of urban suburbs and voids.

2.4.2 Conservation practises on heritage buildings: charters and guidelines

Altering existing building for new purposes and functions is not a new phenomenon. During the Renaissance period historical buildings were converted into new spaces and functions. At the same time, there were no laws or regulations to preserve historical architectural assets. To better understand the evolution of adaptive reuse discipline and laws related to the conservation of historic buildings, Plevoets and Van Cleempoel (Plevoets & Van Cleempoel, 2011; 2013; 2019) and Mehr (Mehr, 2019) stated that the beginning of more theoretical discussion on building adaptation, as a way to preserve historic monuments, emerged in the 19^{th} century. This topic quickly became the focal point of a debate split between two opposite perspectives. The first current of thought was supported by Eugene Emmanuel Viollet-le-Duc (1814-1879) "restoration movement". Viollet-le-Duc considered historic buildings as important containers for the development of society. Preserving historic structure fabric meant finding a new use, making aesthetic and physical changes with the aim of meeting the contemporary functional and spatial needs to apply in the intervention (Viollet-le-Duc, 1854). Opposed to Viollet-le-Duc theory and approach regarding historical architecture, John Ruskin (1819-1900) adopted a more conservative ideology. Ruskin described Viollet-le-Duc approach to monuments as a "destruction accompanied with false description of the thing destroyed" (Ruskin, 1849). For the author the conservation activity of heritage buildings was aimed at the maintenance of the historical and architectural characteristics of the property. The building, treated as a monument characterizing the history of civilizations, assumed only a static and aesthetic vision, not considering its potentials and active and functional reuse policies to extend its useful life and satisfy community needs.

This debate continued in the first decade of the 20th century by Riegl (Riegl, 1903). Riegl distinguished different types of values which he grouped as commemorative values (age, history, memory) and present-day values (use, art, sense of place). His final inclination was to support a form of adaptive reuse linked to restorative approach, preserving building values and memory, but, at the same time, reintroducing it in the society a with new function. Whereas Riegl's approach towards the restoration and adaptation of heritage buildings was theoretical, Camillo Boito (1836-1914) supported the theories of Viollet-le-Duc and Ruskin in more practical terms (Boito, 1893a; 1893b). He criticised both Viollet-le Duc and Ruskin theories of preservation. This author proposed a universal method for every project based on individual building circumstances and characteristics. Boito's eight principles (Table 2.4.2-1) of restoration and conservation of architectural historic buildings were the basis for the subsequent guidelines and regulation for heritage conservation.

	Principles for building adaptation and preservation (1893)
1	Difference of style between the new and the old
2	Difference of construction materials
3	Suppression of profiles or decorations
4	Exhibition of removed old pieces in places next to the preserved building
5	Insertion of the date of renovation in each restored place
6	Descriptive epigraph of the intervention
7	Description and photographs of different work stages, placing it in a nearby public space
8	Visibility of the realized actions

Table 2.4.2-1 Boito's eight building restoration and conservation principles (Boito, 1893).

The influence of Boito's guidelines on Italian and international conservation practises posed the basis for the formulation of Athens Charter in 1931 (Athens Charter, 1931). This charter was the first international policy document that focused the attention on modern conservation and adaptation practises to recovery heritage buildings (Iamandi, 1997; Jokilehto, 2017). The Athens Charter comprised ten main features addressing the cooperation and collaboration by nations for the protection of iconic and historic sites, the formulation of rules and design interventions to define restoration actions and the use of modern techniques and materials like reinforced concrete (Wong, 2017). From a technical point of view, the Athens Charter introduced a philological restoration process, rejecting stylistic interventions and admitting in the case of archaeological restoration only anastylosis.
In 1932 the Superior Council for Antiquities and Fine Arts enacted the Italian Charter of Restoration (Carta Italiana del Restauro, 1932). The document was the first official directive of the Italian State regarding the conservation of the national historical and architectural heritage. The principles listed in this charter are similar to those of the Athens Charter, but included the new theory expressed by Gustavo Giovannoni (1873-1947) regarding scientific restoration. According to the author, every restoration work had to be accompanied by an accurate descriptive and illustrative documentation of the characteristics of the historic construction, as well as professional figure had to exploit all the most modern intervention technologies to achieve optimal restoration results for each selected case study.
The destruction of European historical heritage sites during World War II brought to light the problem of architectural restoration. There was, therefore, the need to introduce new practices concerning architectural restoration that paid the attention not only to the single monument, but also to historical contexts and urban landscapes that constituted the memory of cities evolutionary history. The Venice Charter of 1964 (Venice Charter, 1964) summarized in a concise and understandable way the immutable principles of the architectural restoration methodology, introducing, at the same time, innovative principles based on the importance of the historical aspect of a building and on the conservation of its surrounding urban and natural environment.

Over the years, the need to preserve buildings with historical, aesthetic and architectural values emerges more and more. In particular, in 1972 the Italian Restoration Charter (Carta Italiana del Restauro, 1972), under the reconnaissance of Cesare Brandi, defines the concepts of "safeguarding" the historical heritage as a “set of conservative interventions that can be implemented not directly on the work” and of "restoration" like “any intervention aimed at the maintenance of structural components efficiency, readability of architectural values and transmission to future generations of the importance of historic sites preservation”. In addition, the document lists "prohibited" interventions (style completions, removals, demolitions, relocations of parts to places other than the original) and "allowed" works (additions or small replenishments of parts, cleanings, anastylosis, accommodation of works if they no longer exist, functional renovation) on historic buildings, promoting the use of innovative materials and techniques with the authorization of the Ministry of Education and with regard to environmental issues related to air pollution and thermo-hygrometric conditions.
Further recognition of the architectural singularity of European heritage is introduced in the 1975 Declaration of Amsterdam (Declaration of Amsterdam, 1975). The European Charter of Architectural Heritage affirms the architectural importance of the world's cultural heritage, expanding the conservation activities to urbanized places with a high historical, stylistic and formal interest. This document considers the processes of enhancement and recovery as main objectives to be pursued for urban planning and land use planning. The integrated conservation of the places engages local authorities to collaborate for the protection of fabrics and historical singularities and admits the participation of citizens as a fundamental resource to identify the current functional and social needs to be taken into account in restoration interventions.
The cities expansion and transformation processes have led to a different evolution of the organizational structure of urban spaces. This phenomenon amplifies interventions of replacing the existing with new modern envelopes, erasing important features that characterize the memory of historic contexts. The International Charter for the Preservation of Historic Cities (Washington Charter, 1987) defines the principles and objectives, as well as strategies for safeguarding the urban quality of historical fab-

rics. In particular, the document refers to the maintenance of formal-compositional features, preservation of buildings with valuable architectural and material values, respect for local cultures and traditions and relationships between building and surrounding natural environment. In the field of landscape design and environmental enhancement, society begins to be aware not only of the importance of single historical entities, but also to the preservation action of city centres.

Closer to the present day are the Nara Document on Authenticity (Nara Document on Authenticity, 1994) and the Charter of Krakow (Charter of Krakow, 2000). The Nara Document takes note of the essential role of cultural heritage in societies and recognizes the intellectual and spiritual richness of architectural diversity. It also recognizes aspects of authenticity and social multiculturalism as essential qualitative factors for the development of conservation and restoration policies. The Krakow Charter is linked to the principles contained in the Charter of Venice (1964) with the aim of raising awareness among the community towards the maintenance and recovery of the territory and natural iconic landscapes, as places of human history and culture.

Regarding the reuse, enhancement, conservation and refurbishment of historic industrial sites, the International Committee for the Conservation of the Industrial Heritage (TICCIH) on 17 July 2003 established the Nizhny Tagil Charter (Nizhny Tagil Charter, 2003). In this situation delegates of the TICCIH assert that industrial heritage sites, the production phases, the tools used within them and industrial towns and landscapes must be preserved and reused (Douet, 2012). This charter defines “industrial heritage” as “the remains of industrial culture which are of historical, technological, social, architectural or scientific value”. Factories, mills, warehouses, stores and all the related industrial spaces are considered the evidence of the past productive activities. The principles listed in the document not only pay attention to the social and cultural importance of industrial estates, but also introduce issues relating to the legal, functional, maintenance, conservation, dissemination and promotion of the architectural values of historic factories. With regard to the reuse and recovery of empty buildings, the adaptation of an industrial site for new functional purposes is accepted if existing materials and spaces are preserved and reversible and low-impact design strategies are developed to regenerate dismissed structures and their surroundings. Moreover, industrial heritage provides social sense of identity, representing a tangible landmark of the past city morphology and evolution of the production sector and fixing intangible records of previous lifestyle and historic events in human memories. In Italy, the Code of Cultural Heritage and Landscape (Decreto Legislativo no. 42, 2004) entrusts the central role of protection of cultural heritage to the community and national institutions (Art. 1 and 4), promoting the use of spaces by society (Art. 2), the drafting of rules for their future recovery (Art. 3), the cooperation between different experts (Art. 5) and the development of culture through people knowledge of the past (Art. 6).

A recent document related to the conservation of industrial heritage sites is the TICCIH Principles for the Conservation of Industrial Heritage Sites, Structures, Areas and Landscapes (Dublin Principles, 2011). The principles resume the points listed in the 2003 Nizhny Tagil Charter, outlining guidelines aimed at reusing the industrial historical asset to meet the new needs of the population based on functional, social and cultural inclusivity features. The typological diversity of historic industrial buildings, at the same time, requires careful studies and researches on the architectural and formal characteristics of sheds and the active participation of the population, reconstructing the city context evolution. In addition, the document introduces principles aimed at the digital promotion of the structural and architectural components of historical factories with the aim of increasing the awareness of the population towards the enhancement of reuse actions to reutilise this historic building typology.

Twenty years after the adoption of the Nara Document on Authenticity (Nara Document on Authenticity, 1994), the Nara +20 (Nara +20, 2014) reaffirms the principles contained in the previous document, identifying five key inter-related points that prioritize global actions to preserve the uniqueness of heritage diversity around the world and to engage stakeholders and communities interested in maintaining and transmitting these form of cultural expressions to future generations. More specifically, this document strengthens the importance of people participation, social inclusion and intergenerational responsibility in heritage conservation practises, acknowledging population rights and responsibilities to explore and analyse the role of historic architectural heritage in the field of sustainable development researches in order to promotes innovative approaches of assessing trades-offs and synergies between cultural sites and human behaviours and needs.

The last statement regarding the preservation, reuse and enhancing of unused built heritage for future generations is the Leeuwarden Declaration (Leeuwarden Declaration, 2018). This fundamental document, adopted in the European Year of Cultural Heritage (2018), outlines the main thematic aspects and focal points to achieve smart and quality-based adaptive reuse interventions on building heritage. In particular, it states that the dialogue between heritage and contemporary architecture can be perceived through accurate and strategic refurbishment and conversion interventions of abandoned historic architectures, carefully scanning spatial and natural landmarks, social dynamics, sustainable solutions, costs, building resilience and functional potentials. Adaptive reuse projects ensure flexibility, people participation, multidisciplinary teams, technological innovation, financial viability and architectural quality, providing the re-integration of derelict historic buildings into contemporary urban assets without affecting their architectural features and iconicity.

Worldwide organizations (TICCIH, UNESCO, ICOMOS, Do.co.mo.mo International and ICCROM) and European (E-FAITH) (Table 2.4.2-2) and national institutional associations (AUDIS, AIPAI and Do.co.mo.mo Italy) (Table 2.4.2-3) have the task of controlling and managing the existing industrial heritage with the aim of analysing, protecting, preserving and intervening on these contexts rich of culture and history and easily adaptable to start policies of urban regeneration through adaptive reuse models. The disused industrial heritage represents the physical memory of the production processes of the past and an available resource for the implementation of territorial development policies, through recovery and adaptive reuse activities.

International organizations	*Description*
ICOMOS International Council on Monuments and sites	This institution promotes the conservation, protection, use end enhancements of buildings. The Council also structures international guidelines and documents to ensure actions to protect the historical heritage.

TICCIH The International Committee for the Conservation of the Industrial Heritage	It is the world organization for industrial heritage and promotes the preservation, investigation, conservation, education, documentation, analysis and research of industrial heritage sites.
UNESCO United Nations Educational, Scientific and Cultural Organization	United Nations specialized agency that promotes culture, the enhancement of the architectural heritage and the historical traditions of civilizations. The organization provides for the cataloguing and conservation of sites that, from an environmental, architectural and social point of view, are considered iconic by the world community.
ICCROM Intergovernmental organization dedicated to the conservation of cultural heritage	Association that monitors, preserves and enhances cultural heritage in the different regions of the world, contributing to environmental, social and economic sustainability. It provides Member States with tools and knowledge to preserve existing heritage by pursuing actions to promote, educate society and seek solutions to improve well-being and inclusiveness.
Do.co.mo.mo. International International working party for the Documentation and Conservation of buildings, sites and neighbourhoods of the Modern Movement	Non-profit organization for the classification, valorisation and preservation of modern architectures. This association analyse heritage sites of the modern movement trying to change people thoughts about the conservation technology, history and architectural value of 20^{th} century buildings.
E-FAITH European Federation of Associations of Industrial and Technical Heritage	European platform that promotes the study, development and management of industrial and technical heritage, facilitating the cooperation between European nations.

Table 2.4.2-2 Worldwide organizations for the preservation and valorisation of industrial heritage sites.

Italian organizations	*Description*
AUDIS Associazione delle Aree Urbane Dismesse (Association of Abandoned Urban Areas)	Italian association active in the field of urban regeneration of abandoned areas and building recovery, based on urban, architectural and environmental quality criteria. AUDIS' main objectives concern the promotion of innovative proposals for sustainable building transformation and the study of realized refurbishment interventions on abandoned areas.
AIPAI Associazione Italiana per il Patrimonio Archeologico Industriale (Italian Association for Archaeological Industrial Heritage)	Organization that promotes research activities on industrial archaeology, cultural and environmental heritage with the aim of cataloguing, preserve and enhance existing industrial contexts.
Do.co.mo.mo Italy Italian Association for the documentation and preservation of urban complexes of the Modern Movement	Non-profit association that catalogues, preserves and enhances the cultural heritage of the twentieth century, studying methodologies of safeguarding and intervention on the existing in disuse.

Table 2.4.2-3 Italian associations for the conservation and promotion of historic industrial sites.

2.5 Adaptive reuse intervention typologies on dismantled industrial areas

Adaptive reuse approaches pose quite difficult challenges to architects, developers and engineers. These processes require the respect of urban regulations and rezoning approval. Industrial abandoned sites are fundamental resources for sustainable development. The implementation of architectural policies and functional redesign of interiors breathe new life into an empty and historic industrial context. Giving new uses to old factories must retain the authentic buildings characters and combine modern additions with old parts in a harmonic architectural, spatial and reversible

planning (MacDonald, 2009). Building adaptation interventions involving disused industrial areas can be divided into two distinct design approaches: the first considers building transformation strategies that focus the attention on morphological (Crotti, 1990), historical-conservative (Perego, 1993) and physical obsolescence characteristics (Douglas, 2006); the second analyses the formal, technological and spatial compositions that can be applied on the single disused industrial warehouse (Guadagno et al., 2015; Orhon, 2016; Boarin et al., 2016; Fisher-Gewirtzman, 2016; Tam & Yao, 2018; Morandotti et al., 2019).
A disused industrial site within a consolidated suburban urban context represents a space to be filled and reused, but at the same time it must relate to the environment in which it is inserted. Crotti (Crotti, 1990) in his research makes it known that interventions on disused industrial areas are not singular and disjointed episodes, but they merge unrelated neighbourhoods and promote modern solutions for a new idea of city. The four reuse strategies of disused factories hypothesized by the author refer to a different way of approaching the context. A more conservative view of recovery interventions, based on processes of homologation and integration with the surrounding urban fabrics, is interposed with a negationist vision that aims to safeguard the places, without, at the same time, inserting any function within it. The latter hypothesis does not benefit the development of cities, since it monumentalizes the industrial context without reintroducing its volumes into programmes of sustainable regeneration and urban development and involving metropolitan dissolution phenomena. The morphological hypothesis most connected to the theme of adaptive reuse considers disused industrial contexts as urban voids in which inserting large technological and functional devices, meeting the current needs of society. The fourth possible way to reuse disused industrial warehouses is to recognise the social, physical and legal complexities of the processes of transformation and conversion of industrial assets, but, at the same time, not excluding the possibility to introduce, even temporarily, services that increase the quality of life in the neighbourhood. The study of the iconicity and historical memory of an abandoned site of industrial archaeology involves the preservation of its spaces and structures. Perego (Perego, 1993) divides

the types of transformation of unused industrial sheds into ten different scenarios that take into account the cultural and architectural characteristics of the existing and the relationships that adaptive reuse processes establish with the historic memory of these abandoned places (Table 2.5-1).

Intervention typologies	*Description*
Integral substitution	Conversion intervention of industrial contexts through spatial and functional structure site modification.
Memory safeguarding	Conservative intervention that keeps totally or partially unchanged the urban structures and plants present in the abandoned industrial area, changing the functional apparatus.
Cultural conversion of the building	Conservative intervention of disused production plants, which are converted into museums and cultural areas, preserving industrial components.
Aesthetic and functional safeguarding	Intervention that considers innovative production processes without changing the architectural factories iconic features.
Emphasis on historical values	Total or partial conservative restoration of production plants belonging to industrial archaeology.
Suspended transformations	Industrial reuse measures suspended and available for further conversion opportunities.
Plant relocation	Intervention of decommissioning and relocation of plants no longer compatible with the new envisaged functions.
Typological & functional implementation	Industrial conversion interventions that enhance the aspects of spatial functionality and flexibility, introducing new activities that do not make the characteristics of production sites morphologically recognizable.

Integral conservation	Intervention of preservation and functional and aesthetic preservation of the abandoned industrial site.
Maintaining the existing layout of the area	No interventions. The site remains abandoned and unused.

Table 2.5-1 Morphological typologies of intervention on dismissed industrial heritage sites (Perego, 1993).

Intervening on industrial buildings does not just mean taking care of the architectural and historical quality of the area. The adoption of correct urban regeneration strategies also includes the study of the level of structural and physical obsolescence of the components characterizing the site, in order to understand the types of actions to adopt for reintroducing a disused production area into urban planning strategies. The level of functional and physical degradation due to external environmental agents and non-maintenance of the site can be solved through the implementation of flexible and reversible design approaches and the comparison between old and new (Balzani, 2011; Wilkinson et al., 2014). The physical obsolescence factor is the trigger element for adaptive reuse actions, since on the basis of a precise evaluation of this parameter that developers can choose the best strategy to adopt on existing empty sites (Boarin et al., 2016). The types of intervention to be considered according to the entity of site degradation are described by Douglas (Douglas, 2006) in a biaxial graph with on the x-axis the parameter relating to the risk and obsolescence of the building and on the y-axis the possible recovery solutions (Figure 2.5-1). In particular, four intervention scenarios are highlighted. These hypotheses can range from basic preservation actions, for low level of building decay, to demolition in very bad physical conditions (Table 2.5-2). The types of intervention on disused industrial sites not only focus the attention on the strategies to be adopted on the entire area in relation to the context and historical components, but for each building of the case study it is possible to make considerations regarding the possible spatial and formal compositions to be inserted. Additions, subtractions, insertion of façade elements and re-functionalization of interior spaces are just some of the formal strategies that can be applied through adaptive reuse models on disused industrial contexts (Plevoets & Van Cleempoel, 2011; Guadagno et al., 2015; Orhon, 2016; Boarin et al., 2016; Fisher-Gewirtzman, 2016; Tam & Yao, 2018; Morandotti et al., 2019) (Table 2.5-3) (Figure 2.5-2).

Level of intervention	*Definition*
1 Preservation and maintenance works	Basic adaptation activities to arrest decay.
2 Refurbishment and stabilization	Building adaptation interventions that include major improvement and maintenance works on structural components.
3 Consolidation and remodelling	Medium adaptation works that include high structure treatments and recovery actions, caused by a high level of physical obsolescence.
4 Demolition and reconstruction	Integral substitution of an obsolete industrial site with new constructions.

Table 2.5-2 Recovery intervention on dismissed industrial sites (Douglas, 2006).

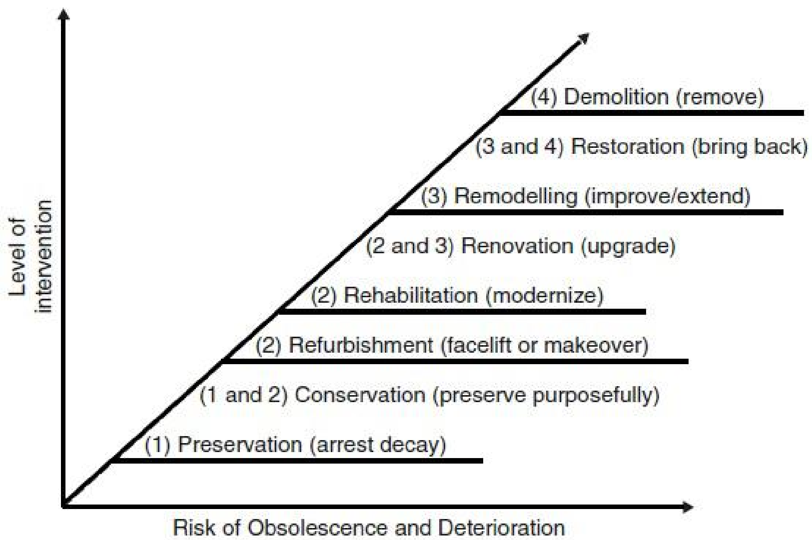


Figure 2.5-1 Range interventions for building adaptation processes (Douglas, 2006).

Adaptive reuse design strategies for the conversion of industrial dismissed sites	***Description***
a. Cladding	Insertion of technological envelopes on the façade.
b. Connection	Connection between separate buildings through walkways or punctual elements.
c. Merge	Union between two or more buildings with volumetric interposition.
d. Interior design	Changes in the interior spaces of the building.
e. Addition	Insertion of new volumes on the building.
f. Subtraction	Removing of building parts.
g. Elevation	Adding one or more floors above the building.
h. Demolition	Complete removal of the building.
i. Intrusion	Punctual insertion of volumes on the building differing in size and shape.
j. Stack/Detach	Insertion of new volumes above the building detached from the roofing plane.
k. Envolve	Incorporating the old building into a new volume totally detached from the existing structure.
l. Outside	Interventions involving the external areas included in the building site.
m. Duplication	Introduction of a new volume spatially and morphologically the same of the existing one, but with different technological and functional interventions.
n. Connection through spaces	Connection between buildings through the design of public spaces and greenery.
o. Landscape and urban art	Connection between buildings by inserting artistic installations.
p. New construction	Construction of new volumes.
q. Excavation	Insertion of underground volumes.
r. Testing	Testing, monitoring and analysis activities.
s. Recovery actions	Recovery activities on existing buildings.

Table 2.5-3 Description of adaptive reuse design strategies for the recovery of abandoned and unused industrial sites.

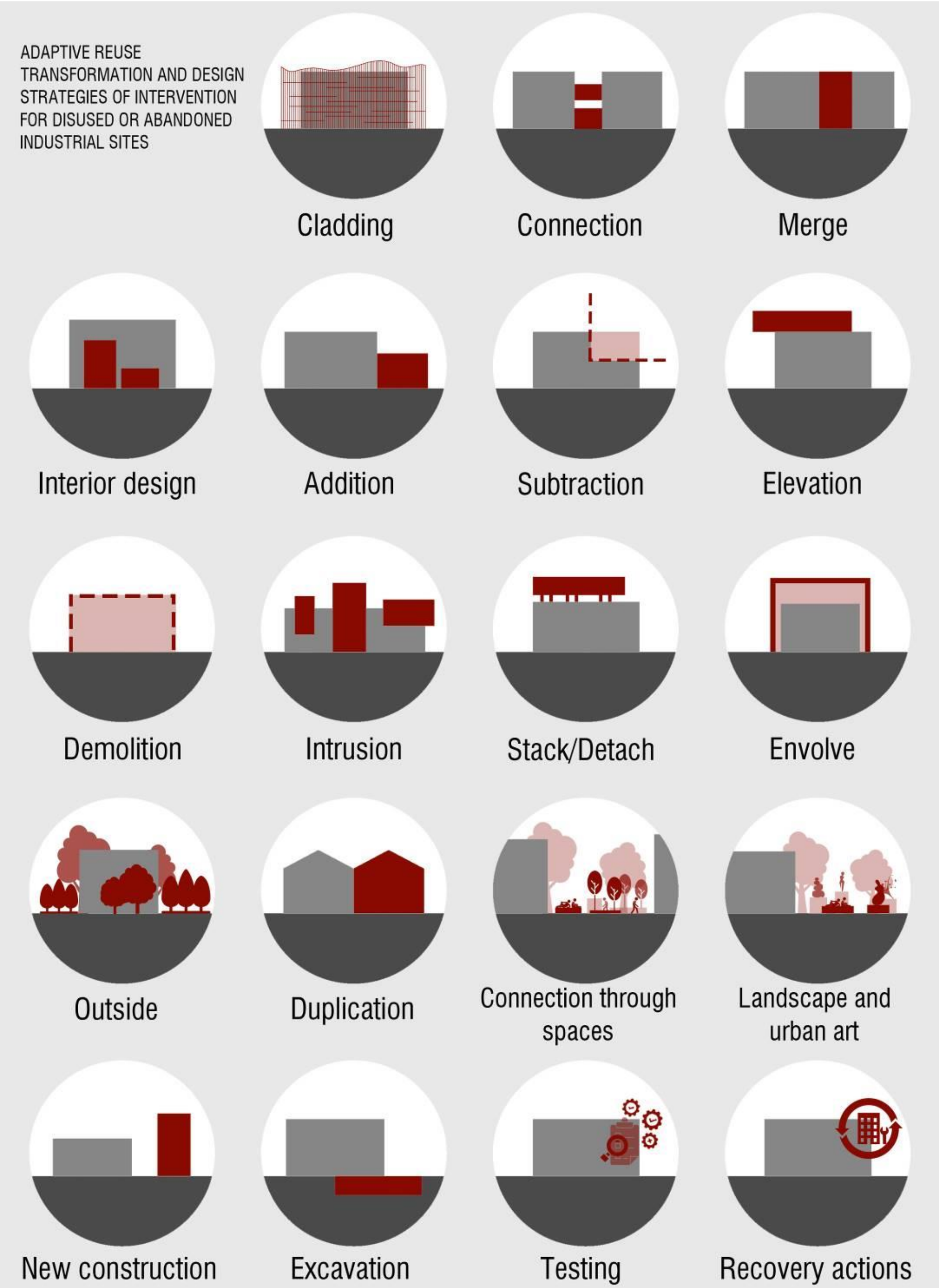


Figure 2.5-2 Adaptive reuse design strategies for disuses industrial sites.

These tactics amplify building architectural quality. In addition, the selection of details and style transform the building aesthetic and interior spaces perception (Brooker & Stone, 2004).
The use of details and architectural features as lights, open spaces, surfaces, covers, openings, new structures and natural landscapes define the new building functions and its characteristics. These contemporary tactics are flexible and economically feasible, not affecting the existing industrial site authenticity and iconicity.
Nowadays, these expedients become essential to develop design strategies able to implement smart scenarios that link the morphological expressiveness of the existing with the new functional role of volumetric additions and the application of technological and spatial solutions (Boarin et al., 2016). Reuse strategies must establish relationships between exterior and interior changes of these macro-containers and the urban environment. These allow to avoid the consolidate relationship between the existing construction and the urban surrounding tissue, giving new values, vitality and identity to industrial contexts, thanks to their new role for community and lifecycle as an attractive signal of districts regeneration.

2.5.1 Abandoned industrial sites functional conversion: a literature review

In the context of the reuse of disused industrial buildings, it is necessary to carry out an analysis of the literature on the possible functions that are most inserted and considered within these large abandoned spaces. The high adaptability of industrial buildings, due to the presence of vast empty surfaces and double height spaces, allows to improve smart policies of conversion and cultural, education, commercial and social functional programmes (Smith, 2012). Over the lifecycle of an industrial derelict site, architectural and functional changes are inevitable (Madanayake & Manewa, 2014). In addition, adaptive reuse functional conversion must take into account social needs, economic feasibility and investments and physical context morphology (Russell & Moffatt, 2001).

Part of the doctoral research focused on the selection and analysis of conference papers, international journals and thesis where the theme of adaptive reuse is associated with the field of industrial regeneration and, in particular, with the choice of functional conversion strategies to be included in existing abandoned warehouses. Data collection phase, regarding the theme of adaptive reuse of industrial derelict sites, is based on the research of published contribution by keywords. All the analysed papers (42) (concerning adaptive reuse, industrial heritage conversions, building refurbishment and functional adaptation approaches) are classified according to the new functional programmes considered by the regeneration conversion activities. Each of the identified documents describes adaptive reuse interventions on abandoned or disused industrial buildings, referring to the functional strategies adopted for the conversion of these unused sites. Some of them consider more cases of industrial re-functionalization, while others introduce design strategies based on an accurate analysis of the surrounding services and the main needs of the population. In addition, in most of the solutions adopted, the transformed industrial site does not present itself as a single-purpose building envelope. In fact, building adaptation processes allow the insertion of multiple services belonging to different functional fields, with the aim of meeting the needs of a larger number of inhabitants. The huge free surfaces of industrial warehouses are flexible to accommodate multifunctional spaces. Table 2.5.1-1 (Table 2.5.1-1) summarizes all the articles reviewed and analysed, identifying for each of them the functional themes that have been introduced through adaptive reuse processes.

As arisen from the analysis carried out, in most of cases adaptive reuse interventions transform abandoned industrial buildings into cultural and entertainment containers (23.80%) with the aim of enhancing tourist attractiveness and quality of life in urban suburbs. Although the implementation of functional programs dedicated to culture, art and entertainment favours phenomena of inclusion and social development, there are many cases of disused industrial sites that are converted into offices (15.75%) and in large shopping centres (15.07) that can offer more job opportunities. These functions can be adapted well to flexible spaces that characterise dismissed sheds.

ARTICLES	Cultural	Education	Offices	Park	Public spaces	Healthcare	Commercial	Sport	Residential	N. of industrial sites analysed
DEH, 2004	1		2		1		1		2	4
Cantell, 2005	1	1	1		1		2		1	3
Rutcosky, 2007				1	1			1		1
Zhang, 2007	18			18	18					18
Farrow, 2008	2	1	1	1	2			1	1	3
Brugè, 2009	1									1
Campagnol, 2011	3	2			3		1	1		3
Zanetti, 2012				1	1				1	1
Setti, 2012	1		1				1			1
Currà et al., 2012	1	1	1		1		1		1	1
Roido et al., 2013	1		1		1		1			1
Mengusoglu & Boyacioglu, 2013									1	1
Benassi, 2013	1				1		1			1
Conejos, 2013	2	1	4		2	2	4	1	3	5
Kee, 2014									2	2
Ferretti et al., 2014	4				4		4			4
Fouad et al., 2014	1				1		1			1
Materazzi, 2014	5	1	2	5	5		1	5	1	5
Yuceer & Vehbi, 2014	1	1			1		1		1	1
Boarin et al., 2016	6	3	7				4	1		9
Chen et al., 2016	19	28	24	5	6		16			37
Louw, 2016							1		1	1
Conejos et al., 2016			3				1		1	3
Blagojevic & Tufegdzic, 2016	1				1		1			1
Bianchi & Turturiello, 2016	36	2	3	6	6	1	12		10	58
Giuliani et al., 2017	1	1	1		1					1
Kiroff & Parris, 2017									1	1
Bylemans & Vallet, 2017						1	1			1
Sayraiyan & Tumer, 2017	1	1								1
Conejos et al., 2017	9	4	12		6		6		16	20
Robiglio, 2017	4	3	10	1	3		10	3	1	15
Rodopoulou, 2017	1		1							1
Tappe, 2017	3	1	1		3		3	2	2	3
Li et al., 2018	1	1	1							1
Kim, 2018	5	5	6		5		6		3	7
Busra, 2018	2		2	1	1		1		2	3
Singavi, 2018			2		1		2			2
Muskara, 2018	1	1	1	1	1		1			1
Heinz, 2018	1	1			1					1
Bottero et al., 2019	3	3	4	2	5		3		4	7
Fajarwati & Wulandari, 2020	1	1	1							1
Sanchez-Montanes & Castilla, 2020	1	1		1	1		1			1
TOTAL	139	64	92	43	84	4	88	15	55	233
%	23.80	10.96	15.75	7.36	14.38	0.68	15.07	2.57	9.42	100

Table 2.5.1-1 Paper data collection and functional analysis of disused industrial factories conversion.

The modularity of office spaces and rooms can be well managed within an industrial shed. The large lights and the regular structural apparatus guarantee enormous spatial flexibility. The same modular spatial scan is also adopted for commercial functions unless the service to be inserted requires all the space available (supermarket, shopping centre and multistore). An increasingly growing modern strategy of re-functionalization through adaptive reuse approaches concerns the transformation of disused industrial sites into residences (9.42%). Disused factories, silos, former warehouses and old breweries located within residential consolidated peripheral contexts are influenced by the functions already existing in the district. At the same time, the programmes for transforming these sites into residences also include functions that strengthen sociocultural links within the neighbourhood and public spaces, promoting community relationships (14.38%).

Decommissioned industrial construction incorporates high levels of adaptability and functional flexibility that facilitate the improvement of spatial re-functionalization activities, anticipating the accelerating rhythm of change and reducing future social impacts (Nakib, 2010).

2.5.2 Key design factors for building adaptation

Buildings change their features and characteristics during time. In particular, industrial dismissed sites have undergone a process of physical degradation and abandonment over time. Their futility, due to the sudden development of the tertiary sector and new community needs, has led to the creation of large urban voids. However, it also has brought to light the opportunity to develop new concepts of sustainable contemporary cities based on the recovery and reuse of the existing abandoned latent resources. Factories adaptive reuse processes accommodate new changes in urban and social structure. However, it is fundamental to analyse and classify the key design factors that affect building adaptation interventions. Building adaptation models must consider external and internal design factors (Ryu, 2014). They can be classified in seven main categories: physical, economic, functional, technological, social, legal and political (Wilkinson et al., 2014; Mohamed & Alauddin, 2016; Gunce & Misirlisoy, 2019; Vardopoulos, 2019) (Figure 2.5.2-1).

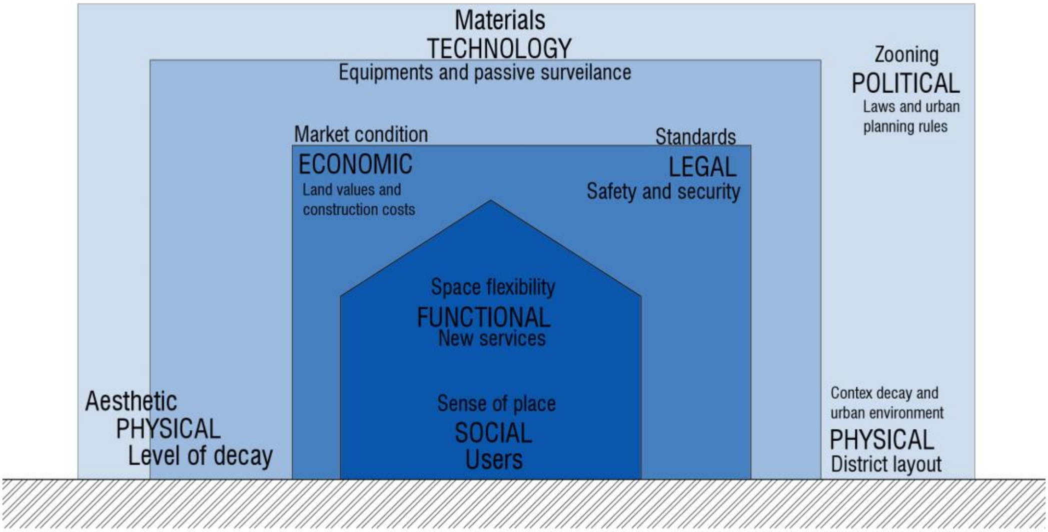


Figure 2.5.2-1 Internal ed external factors that affect building adaptation processes (Ryu, 2014).

Architectural interventions and refurbishment actions are necessary to amplify industrial site life cycle, meeting the current society needs. Intervene on building structural and physical components allow to upgrade building performances to guarantee high indoor comfort quality, space reversibility and flexibility and energy efficiency. The re-use of a disused industrial building implies a careful study of the different components of which it is formed. Brand (Brand, 1994) identifies six different layers that can explain the complexity of the physical structure of a building. Each part needs different interventions, monitoring, analyses and maintenance action management, not neglecting the study of the physical degradation of materials and components. The shearing layers graph (Brand, 1994; Douglas, 2006) shows the building complexity, composed by a set of different components (site, structure, skin, services, space plan and stuff) with different timescales of maintenance ad obsolescence evolution (Figure 2.5.2-2). Each layer has a different life expectancy in relation to the physical building performance capacity of each element. The analysis of life expectancy allows developers, architects and engineers to predict innovative intervention of refurbishment and reuse, changing the design capacity of each component for further transformations (Ryu, 2014).

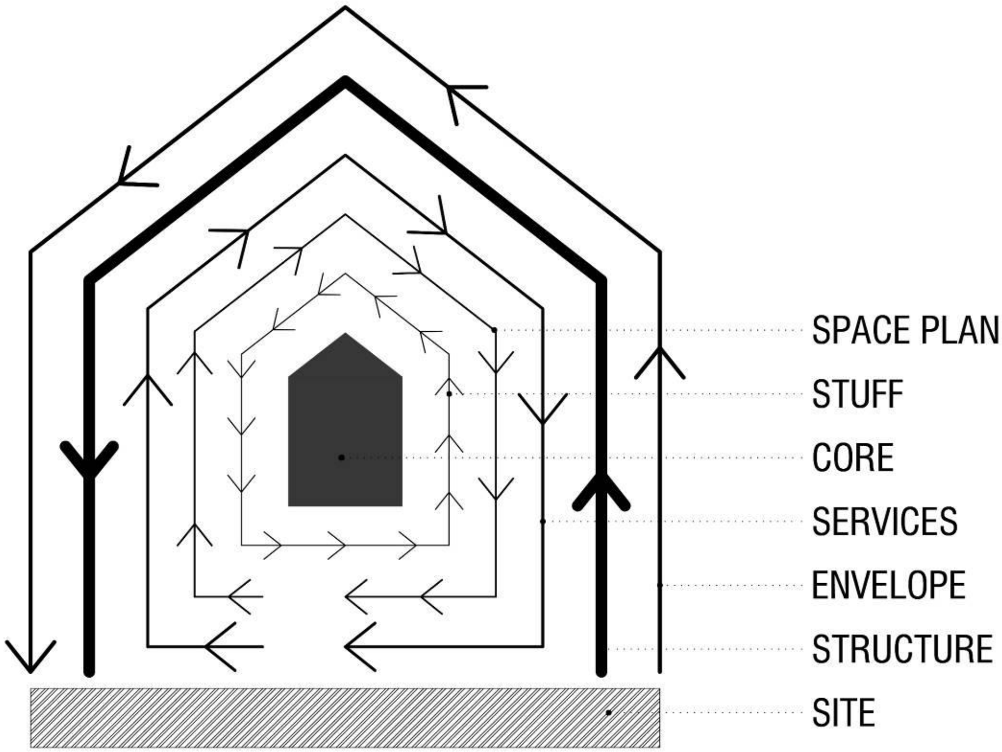


Figure 2.5.2-2 Shearing layers graph (Brand, 1994; Douglas, 2006).

Physical design factors are the most prevalent category to consider in adaptive reuse conversion processes (Wilkinson et al. 2014). This category of attributes analyses the level of obsolescence of existing components and environmental pollution (Douglas, 2006), the layout of the industrial site in relation to its orientation and architectural-morphological shapes disposition in the context and the characterisation of spatial, volumetric, recovery and conservation strategies to apply through adaptive reuse policies (Guadagno et al., 2015; Boarin et al., 2016; Fisher-Gewirtzman, 2016; Gunce & Misirlisoy, 2019; Morandotti et al., 2019). Building height (Gann & Barlow, 1996), construction typology and frame conditions are important features to account in adaptation procedures (Wilkinson et al., 2014). For example, steel structure frames are more adaptable and reversible than reinforced concrete structures (Kincaid, 2002). In addition, floor size and spaces layout analyses contribute to understand the potential function to introduce in the interior areas. Main services can be located in the core building spaces, characterizing by high level of flexibility and vast free surfaces (Gann & Barlow, 1996; Snyder, 2005; Szarejko & Trocka-Leszczynska, 2007). Building interior layout affects the ability to compose dynamic spaces. A spatial efficient subdivision allows to host multiple useful services for the community, delivering each function to various building sections, easily linked and accessible (Wilkinson et al., 2014). A central and regular function location facilitates adaptive reuse interventions, minimizing corridor and empty areas. Site decay conditions influence adaptation potentials, especially when occurs pollution and materials constraints (Bullen, 2007). The presence of constraints related to environmental soil and air level of pollution, due to the presence in the past of productive buildings, changes the feasibility of the intervention, requiring higher reclamation and construction costs and times.

In the economic field, the factors that most affect the feasibility and effectiveness of adaptive reuse interventions concern the costs of design, construction, labour, maintenance and recovery of the disused industrial site. The international debate considers adaptive reuse as a transformation model cheaper than demolition (Highfield, 2000; Douglas, 2006). At the same time, if physical, technological and environmental conditions show a high level of degradation, the monetary burdens and investments to activate building regeneration and recovery project will increase exponentially. Owners consider the economics of adaptation measures as the starting point to evaluate the feasibility of the conversion process, evaluating risks and government incentives (Wilkinson et al., 2014). Monetary incentives and fiscal concessions encourage the development of transformative renewal actions towards the refurbishment of derelict heritage sites, involving private investors (Greffe, 2004; Conejos et al., 2016).

Economic design factors include marketability features (level of demand and supply) and create new businesses and job opportunities (Wang, 2011; Ijla & Brostrom, 2015), ensuring structural and touristic shift in the local economy (Vardopoulos, 2019). Low cost reuse strategies are valuable compromise to refurbish old industrial buildings, but, at the same time, attract a degree of private investors that can support future adaptation and transformation interventions (Kirovovà & Sigmundovà, 2014).
In terms of functional building design, accessibility and flexibility issues make adaptive reuse processes easier to convert industrial abandoned sites. Site modularity and plug-and-play building elements allow to modify the construction asset of services and wall systems, perceiving dismantlability and reversibility features (Arge, 2005). In addition, vertical and lateral extensions amplify building useful surface, without impacting on the existing structures (Arge, 2005). These scenarios increase the number of occupiers and spaces elasticity. In particular, the presence of entrances and exits allows an optimal management of people floods and conditions of security and safety (Kersting, 2006; Remoy & Van der Voordt, 2007). The more availability of access points ensures a high space flexibility to develop feasible and adaptable design solutions. The key attribute of functional design criteria regards services selection process. As mentioned in the previous paragraph, the identification of adequate functions in relation to the analysis of site surrounding context and social needs promotes modern visions of suburban areas, activating urban regeneration policies. The choice of the functional programme to insert in industrial building recovery projects is closely influenced by the intrinsic spatial characteristics, convertibility and interchangeability of the shed (Conejos et al., 2015), not neglecting the possibility of designing paths that make the use of all the hypothesized services in the design phase better.
The society high demand for living comfort quality and technologies construction and shading requirements lead designers to insert smart solutions on building envelope and new materials, respecting cultural heritage features. Technological design attributes take into account physical characteristics of the existing buildings and propose innovative interventions approaches to preserve architectural values, increase energy efficiency and use modern and natural materials (Wilkinson & Remoy, 2017). Material

reuse and recycle reduce energy consumption and transport costs (Kirovovà & Sigmundovà, 2014), extending their useful life. By a precise analysis of materials level of decay, architects and engineers can evaluate and estimate existing building potentials to activate feasible refurbishment actions and the cost effectiveness of the interventions. At the same time, adaptive reuse activities do not exclude the use of sustainable and more efficient modern materials with regard to the thermal and acoustic insulation of the building envelope. New windows with thermal insulation qualities or facade technologies can replace the old ones, without affecting building architectural features (Kirovovà & Sigmundovà, 2014). Passive design strategies, glazing, shadings, natural ventilation and security systems are only some of the possible strategies that the conversion projects of warehouses should include (Umar et al., 2019). The implementation of passive design solutions according to functional spaces division guarantees optimal heating and ventilation, achieving optimal indoor quality (Kirovovà & Sigmundovà, 2014). Smart technological solutions allow to absorb energy from natural renewable resources. In particular, photovoltaic panels, smart collector glasses, shading systems and geothermal system can achieve these goals, enhancing building self-maintenance performances (Thomas Ng et al., 2014).
Adaptive reuse processes involve a large number of stakeholders and decision makers. It is, therefore, important to identify all the main figures involved in the conversion and recovery of disused industrial factories. Social design criteria synthesized all the professional figures and users that can participate to adaptive reuse interventions. Mohamed and Alauddin (Mohamed & Alauddin, 2016) focus the attention on seven main decision agents that can affect decision-making processes (investors, producers, marketeers, regulators, policy makers, developers and users). Each stakeholder category listed above refers to different professional affiliations and intervenes only in specific adaptive reuse conversion stages. All these figure influence differently design choices of conversion (Alauddin & London, 2011). An ineffective decision strategy, made in a preliminary design phase, may compromise all the future transformation steps. Success adaptive reuse projects also account people sense of place. An active society participation in planning steps makes community aware of the potentials of

building adaptation of decommissioned sites, achieving life quality conditions and new usable spaces for users without deleting building memory (Gunce & Misirlisoy, 2019). It facilitates stakeholder's social analysis, meeting the current needs of population with the introduction of new services and public spaces.
Legal issues are strictly related to ownership, respect of urban standards and regulations (Wilkinson et al., 2014). Building adaptation, in fact, is conditioned by owners and lessees' behaviours in relation to the type of refurbishment intervention to apply on an abandoned factory (Swallow, 1997). In particular, institutional owners seek to maximise profits in properties or buildings that require reuse activities, engaging professional consultants to analyse the economic and physical potentials of adaptation measures (Wilkinson et al., 2014). Regarding the respect of quality standards Conejos et al. (Conejos et al., 2015) and Umar et al. (Umar et al., 2019) list the main legal attributes to assess building comfort indoor (indoor quality, clean environment, environmental performance measures, building quality, energy efficiency, noise control), safety (provision of disabilities access, risk management, occupational health) and security of users (fire protection, direct and passive surveillance).
The last main driver category includes all the policies of zooning and planning regulations to examine for correct adaptation interventions (Umar et al., 2019). Political design criteria are useful to achieve smart and efficient regeneration and urban transformations, taking into account land uses, space patterns, surrounding morphology, adjacent enclosures and site zooning classification (Conejos et al., 2015).
These studies must be implemented in the preliminary design stage to promote appropriate measures for the evaluation of ecological footprint and to develop modern conversion strategies for future sustainable cities. However, the respect of building urban and environmental codes narrows the possible adaptation scenarios, amplifying the complexity of decisions and warehouses conversion actions (Wilkinson et al., 2014). Governmental institutions must play an active role in the management of regeneration measures for the refurbishment of urban industrial voids, pursuing sustainability and efficient conversion strategies of adaptation, understanding society

needs demand and encouraging the implementation of adaptive reuse strategies of conversion (Kincaid, 2000).

2.5.3 Risks in building adaptation processes

The transformation of disused industrial buildings, if not well managed, involves the emergence of risks that may affect the design, construction and maintenance procedures of the building complex. Design, logistical, structural and architectural problems can occur at any time during the building conversion process. Risk management and forecasting in the building adaptation phases increases the effectiveness of the reuse intervention, reducing the monitoring, analysis, design, construction and maintenance times of the dismissed industrial context. The complexity of adaptive reuse models and the presence of physical risks and high level of obsolescence are difficult scenarios to analyse for most of the clients (Langston, 2010). In addition, risks present a high level of uncertainty and are difficult to deal with, since they require a constant design phases monitoring and a theoretical and practical management (Wang & Zeng, 2010). However, through good risk management practises, uncertainties and procedures impacts are minimized, ensuring social, design and environmental benefits.

Considering the seven main categories of factors influencing adaptive reuse processes, identified in the previous paragraph, seven different areas of risk can be distinguished: physical risks; economic risks; technical and technological risks; functional risks; social risks; legal risks and political risks.

Abandoned industrial sheds, in most cases, are in very high conditions of decay and obsolescence. The physical risks that may arise during the analysis and site monitoring phases concern environmental and architectural features. The damages caused on the natural environment by the presence of industrial decommissioned structures can be linked to soil and air pollution constraints, which have a significant influence on intervention and reclamation procedures, as well as on building conversion costs. In addition, features of architectural complexity (Shipley et al., 2006; Finch & Kurul, 2007; Eyuce & Eyuce, 2010; Shen & Langston, 2010; Wilkinson et al., 2014), structural integrity (Bond, 2011) and durability of materials (Bullen & Love, 2011c; Wilkinson et al., 2014) intrinsic in the adaptive reuse project increase the timing of plan ideation, design and realization, reducing the effectiveness of the intervention and the maintainability of warehouse components and layers (Bullen & Love, 2011b; Wilkinson et al., 2014). Risk conditions may also be associated with the analysis of the existing conditions of disused factories. Damaged structural parts, collapsed roofing and the presence of hazardous materials in building components are high risks for the health, safety and security of workers.

As a result, physical obsolescence factors increase economic risks. A high degradation of the structure, the complexity maintenance activities of brownfields and the adoption of environmental recovery and protection interventions exponentially increase the unforeseen costs of conversion works (Douglas, 2006; Remoy & Van der Voordt, 2014). Industries reuse activities cannot be convincing and innovative in the construction market, not attracting potential buyers and lenders and remaining partly or totally unused with large economic losses (Shipley et al., 2006; Remoy & Van der Voordt, 2014).

Not to be overlooked are the spatial and morphological aspects of the disused industrial site. While, on the one hand, the physical degradation of the building increases costs, on the other hand, the presence of spatial situations incompatible with the functions envisaged make it impossible to achieve adaptive reuse efficient strategies. (Wilkinson et al., 2014). Small, inflexible and immutable spaces are difficult to fill with avant-garde functions useful for contemporary societies, not ensuring accessibility requirements (Finch & Kurul, 2007). At the same time, errors in the social and morphological analyses and shortcomings within a neighbourhood cause discrepancy between the services inserted in the building functional program and the current needs of the population. This involves social risks including the non-use of the good by the local community.

Problems that may arise during the testing and use phases of the new building involve the technological field with particular reference to the quality of indoor comfort safety and safeguarding systems (Wilkinson et al., 2014), façade and roofing shielding technologies, thermal and acoustic insulation performances (Finch & Kurul, 2007) and ventilation and natural lighting solutions (Bullen & Love, 2011c; Langston, 2010). Low-quality technological systems do not guarantee optimal liveability of spaces, as well as bring high energy consumption.

In the legal and political field, the main problems related to the activities of recovery and building transformation focus mainly on two main points: the first theme concerns the long deadlines to obtain expropriation and change of use permits, projects approval and energy certifications (Douglas, 2006); the second aspect is related to compliance with the existing building code and regulations regarding the conservation of the historical and architectural values of industrial sites (Shipley et al., 2006), the fire protection requirements (Bond, 2011; Bullen & Love, 2011b), disability and accessibility standards (Wilkinson et al., 2014), indoor comfort quantitative parameters and performances (Langston, 2010) and their actualisation with international climate charters and land protection plans recommendations (Conejos et al., 2012). Long bureaucratic times make the building, once transformed, no longer innovative and useful to meet the new needs of the community, changed over the years. Non-compliance with urban planning regulations and laws in the field of performance, accessibility and firefighting issues are design lacks legally and politically punishable. The no respect of recovery and urban planning rules may involve the closure of the site or the adoption of corrective redesign activities, not benefiting on times and costs for the realization of adaptive reuse processes on abandoned warehouses.

The risk and opportunity management improve the effectiveness of the planning intervention phases (Olsson, 2008) and it's beneficial for the improvement of efficient adaptive reuse strategies. A correct management of constraints consists in the identification, analysis, assessment and control of potential risks that can occur before, during and after the factory transformation processes (Fan et al., 2017; Mallawarachchi et al., 2018). Risk responsive strategies ensure the adoption by designer, architects, engineers and professionals of proper constraints management plan to identify in time problems, resolving them with smart solutions.

2.6 How to simplify decisions in complex design contexts: the adaptive reuse Multi-Criteria Decision-Making (MCDM) approaches in building construction and recovery

Adaptive reuse strategies allow to achieve sustainability issues and ensures continuous building operation, increasing factories functional life (Mohamed & Alauddin; 2016). Analysis, monitoring, design and construction phases for the reuse of abandoned industrial buildings are difficult to manage. Making optimal decisions in the context of the refurbishment and reuse of existing abandoned warehouses and industrial sites is complex (Douglas, 2006; Wilkinson et al., 2009; Alauddin, 2014). Decision-making models for the recovery of abandoned buildings can be considered as a dynamic and easily manageable multicriteria tools. These approaches evaluate multiple factors, scenarios and functions that can influence, in a positive or negative way, the performances of the adaptive reuse intervention, trying to extrapolate the best strategy of conversion in terms of economic feasibility, project quality and spaces flexibility (Vizzarri & Fatiguso, 2019). The study of stakeholders' behaviours and experiences is fundamental to implement feasible sustainable strategies of adaptive reuse for urban development (Wang & Zeng, 2010). In addition, the different stakeholders' views about possible reuse interventions don't facilitate the hypothesis and planning of efficient urban and design policies. Choosing how to reuse a disused factory is a difficult problem to solve if architects, engineers, urbanists and professionals thoughts and purposes do not agree with each other. Such situation favourites the appearance of conflicts between professionals and society (Yildirim, 2012).
In fact, the different background of decision makers, involved in the conversion activities, outlines a series of independent and disconnected scenarios. Therefore, the organization and management of criteria and parameters that affect building adaptation processes is important to have an overview of the possible planning choices and stakeholder's actions. The opportunity to develop, in a single tool, universal strategies for several case studies can facilitate stakeholders' decisions, especially in the preliminary design stage. The range of available options for adaptive reuse interventions on abandoned industrial sites is vast. Efficient monitoring and control activities of building life cycle steps guarantee the study of feasible, flexible and adaptable refur-

bishment solutions for technological, functional and physical optimization of building performances. Bullen and Love (Bullen & Love, 2011a) analyse, in their researches, three main factors that influence the decision-making apparatus. The three criteria are defined as capital investment, asset condition and regulation (Bullen & Love, 2011a) (Figure 2.6-1).

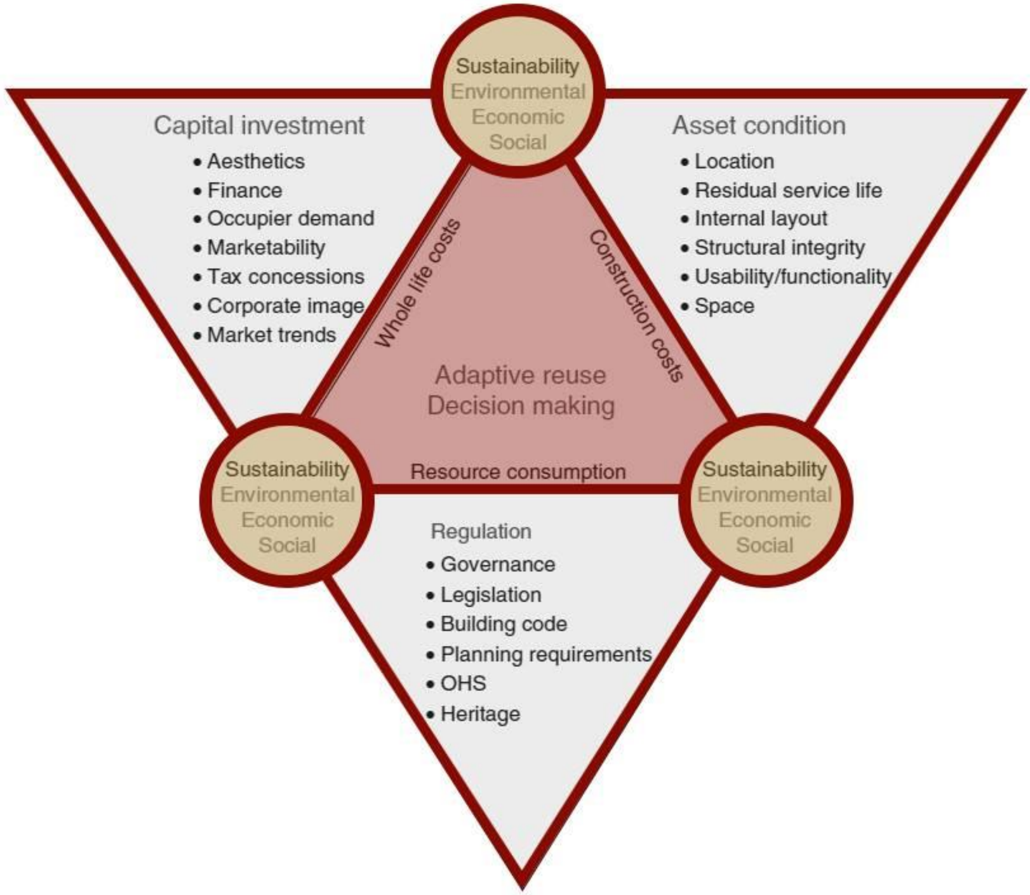


Figure 2.6-1 Bullen and Love Adaptive Reuse Decision-Making Model (Bullen & Love, 2011a).

To perceive sustainability requirements for the development of future smart cities, stakeholders decisions and planning behaviours must consider environmental (energy efficiency, emissions and resource consumption), economic (whole life cycle costs and construction costs) and social (amenities, streetscape, community consolidation, and proximity to transport hubs) issues (Figure 2.6-2).

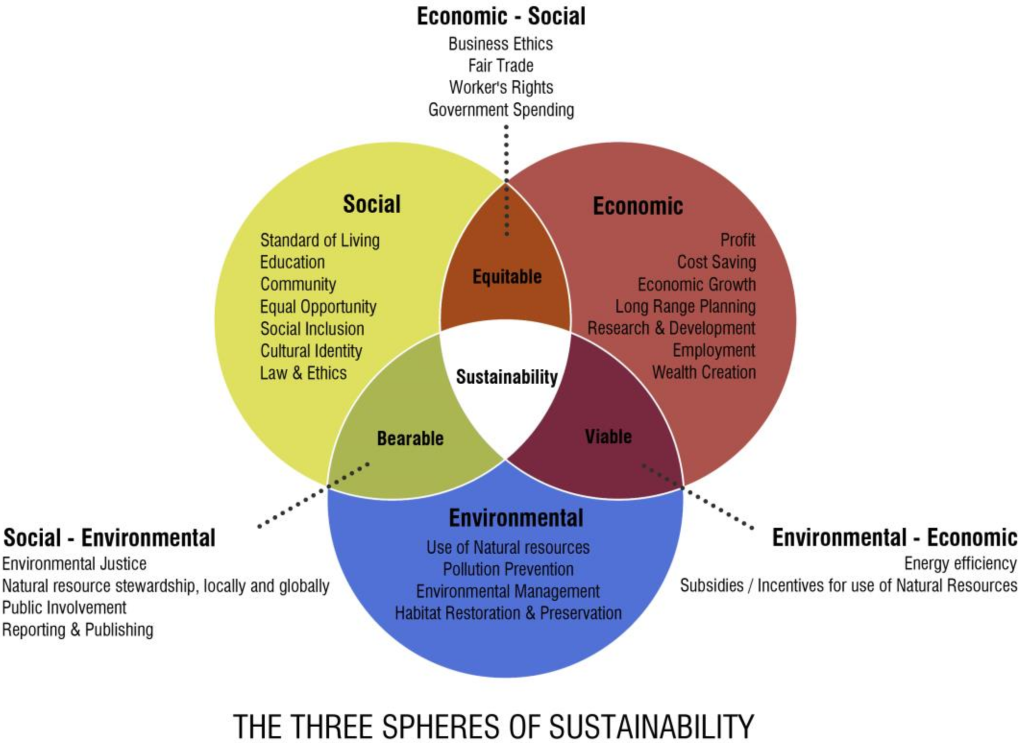


Figure 2.6-2 The three spheres of sustainability scheme.

With a view to the spatial and functional reuse of decommissioned peripheral contexts, the concept of adaptability plays a major role to assess effective design and conversion choices. Reusing optimally dismissed and empty spaces generates opportunities to extend buildings life cycle, enhancing user's wellbeing and safety in terms of health, comfort, life quality, social interactivity and security. Moreover, the viability of adaptive reuse models can be pursued understanding, in the preliminary planning steps, the impacts that affect communities' relationships and urban environment, as well as the economic investments and costs useful to update contemporary configurations and technologies (Bullen & Love, 2010; Bullen & Love, 2011a). It is, therefore, necessary that stakeholders' decisions for the regeneration and refurbishment of unused contexts are oriented towards smart options to reduce non-renewable resources and energy consumption, retain original building's embodied energy without incurring in their demolition, and preserve natural surrounding landscapes and morphologies, ensuring a minimum environment perturbation. Taking into account the economic sphere, building adaptation policies must implement effective functions, reducing materials consumption through time, taking full advantages from technologies and passive solutions and minimising costs and times in order to maximise future profits. From a social point of view, professionals and experts actions are directed to satisfy continuously the common and changing needs of population and strengthen connections between peripheries without harming the neighbourhood or compromising future generations, preserving cultural traditions and society identity and favouring inclusion and multiethnicity (Bullen & Love, 2010; Nakib, 2010; Tam & Hao, 2018). In accordance with these affirmations, the double triangular correlation scheme is an effective system to explain the criteria relationships that can condition the preservation, design and refurbishment interventions of building transformation. The correlation of the three main factors, located in the corners of the triangular graph, with the previously listed pillars of sustainability (environmental, economic and social spheres) that compose the junctions of the adaptive reuse decision-making framework, allows to highlight the main benefits and constraints involved in building adaptation judgment processes, facilitating the management of dismissed volumes stock (Bullen & Love, 2011a;b;c). In particular, the capital investment factor focuses the attention on actors considerations about development and construction costs, operational costs, marketing and maintenance requirements in order to quantify the entity of the intervention transformation, understanding if there is the possibility to improve feasible reuse actions with a subsequent extension of building life expectancy, instead deciding to demolish and erect new technological structures. Dismissed contexts suitability and relationship with the surrounding areas features are two of the main sub-attributes that affect stakeholders' choices for adaptive reuse interventions. More specifically, the asset condition factor outlines physical (building decay, structural integrity or damages and site layout), spatial (dimensions, internal reorganisation, spaces flexibility and adaptability) and environmental (location, quality of the natural and urban environment and retention of embodied energy) drivers and barriers that can develop or compromise functional decision policies on tangible built components. Sustainability initiatives to rethink the built environment morphology must relate with regulations and national codes to achieve innovative outcomes. At the same time, legislation, planning requirements and urban standards amplify the complexity of decision-making processes, being identified by participants as restrictions that can hinder adaptive reuse conversions (Bullen & Love, 2011a). The mentioned decision-making model assists developers and professional figures to provide better choices and design solutions about built assets, outlining critical issues that can arise during adaptation works.

Stakeholders' decision-making choices can be simplified by using Decision Support Systems (DSSs). These types of approaches evaluate the criticalities that can compromise building efficiency and usability, helping stakeholders in the selection of innovative and reversible reuse scenarios (Sangiorgio et al., 2018a). The development of innovative and smart strategies of adaptive reuse can extend the useful buildings life without incurring in their demolition (Yung & Chan, 2012).

Multi-Criteria Decision-Making Analyses (MCDMA) tools have become increasingly popular in Decision Support Systems (DSSs) for building refurbishment and reuse purposes. MCDMA methods reduce the recurrence of planning and construction constraints in the conversion process, finding efficient refurbishment solutions. In synthesis, multicriteria systems can be described as multi-objective selection and decision-making approaches, suitable for addressing complex problems featuring by high level of uncertainty, conflicting items, complex qualitative and quantitative data and different design solutions (Wang et al., 2009). These multi-attribute applications not only catalogue and control a wide spectrum of information and parameters, but also support decision-making processes, providing well-developed and designed evaluation methodologies.

Many authors have studied the topic of adaptive reuse, focusing on the development of innovative applications that measure and increase the potential of building refurbishment, through choice factors. The identification of appropriate tools of decisions management can provide efficient reuse strategies. According to Fournier and Zimnicki (Fournier & Zimnicki, 2004) the formulation of specific guidelines facilitates developers in the identification of sustainable criteria and parameters for industries regeneration actions, aiming to enhance marginal contexts and preserve existing obsolete structures. In addition, adaptive reuse strategies should accomplish population needs, as well as they must be financially and technically feasible (Pearsons & Sullivan, 1995).

The existing literature regarding building refurbishment and adaptation processes explains different multicriteria decision-making approaches and tools. These multiple-choice selection models consider qualitative and quantitative data and rank adaptive reuse solutions through the evaluation of building conversion potentials. Craig Langston develops a methodology to prioritise adaptive reuse projects considering financial, environmental and social factors (Langston et al., 2008). The Adaptive Reuse Potential (ARP) Model evaluates building adaptive reuse potentials starting from the calculation of the physical building life and the analysis of the construction level of obsolescence. This method is implemented on different typologies of case studies in order to provide a reasonable straightforward remote application to estimate effective useful life and ARP score in existing building stock (Langston, 2008; 2012; Langston et al., 2013; Wilkinson et al., 2014). On the basis of Langston's ARP Model, Sheila Conejos validates the AdaptSTAR (Conejos, 2013a; Conejos et al., 2013; Conejos et al. 2014). This modern design evaluation tool is a weighted checklist that calculates the efficiency of building refurbishment actions through the quantification of project quality parameters. Linkov et al. link Adaptive Management (AM) methods with MCDMA to simplify stakeholders' decisions, structuring a robust framework for a wide range of problems in construction planning and energy efficiency topics (Linkov et al., 2006). The Multi-Attribute Value Theory (MAVT), firstly described and applied by Fishburn, Raiffa and Keeney (Fishburn, 1967; Keneey & Raiffa, 1976), is used by Ferretti et al. (Ferretti et al., 2014) to address problems that involve a finite set of alternatives, aiming to rank different scenarios of interventions for the reuse of historical

buildings. The SWING Weight tool (Parnell & Trainor, 2009) is used in MAVT to quantify criteria weights on the basis of stakeholder's preferences.
Multicriteria evaluation models are also adopted for the regeneration of large-scale urban areas. Bottero and Oppio evaluate the feasibility of adaptive reuse strategies for abandoned industrial buildings in complex decision-making contexts using the Preference Ranking Organisation Method for Enrichment Evaluations (PROMETHEE) (Oppio et al., 2017; Oppio et al., 2018; Bottero et al., 2018a; Bottero et al., 2018b). The model, proposed by Brans (Brans, 1982) and subsequently implemented by Brans and Vincke (Brans & Vincke, 1985), Brans et al. (Brans et al., 1986) and Brans and Mareschal (Brans & Mareschal, 1992; 1995), ranks a set of alternatives when multiple conflicting criteria and stakeholders are involved. The PROMETHEE application verifies which action outranks the others, using pairwise comparisons.
Defining the correct allocation of resources for building refurbishment and adaptation provides a meticulous analysis of design criteria, stakeholders' preferences and market effects that can affect adaptive reuse strategies (Bottero et al., 2019). Decision makers, in the preliminary and monitoring phases of building adaptation and transformation interventions, have to consider not only socio-economic aspects, but also society needs, technological systems and hazards. Misirlisoy and Gunce (Misirlisoy & Gunce, 2016) implement a qualitative approach for the selection of adaptive reuse strategies, according to stakeholders' preferences and regulations for the estimation of functions appropriateness on heritage sites. Vardopoulos (Vardopoulos, 2019) uses fuzzy Decision Making Trial and Evaluation Laboratory (DEMATEL) technique to visualize complicated causes and effects of factors into an intelligible system (Falatoonitoosi et al., 2013), evaluating relationships in adaptive reuse process of industrial buildings. Giuliani et al. (Giuliani et al., 2017) adopt the Multi-Attribute Decision Analysis (MADA) for the selection of the best grain silos to reuse for touristic and commercial aims, ranking solutions on the basis of a set criteria and constraints. Wang and Zeng (Wang & Zeng, 2010) rank reuse scenarios for the conversion of heritage buildings through Analytic Network Process (ANP) (Saaty, 1996) and Delphi Method (Ishikawa et al., 1993). ANP is a comprehensive multicriteria decision-making

model that provides comparisons between criteria, evaluating their interdependencies and weights. The Delphi Method synthesizes and quantify experts' opinions to restrict design choices, identifying prevalent factors or behaviours (Ono & Wedemeyer, 1994). Other frameworks advanced to assist decision-makers in complex decision regarding adaptive reuse potentials of existing abandoned buildings are TOBUS (Caccavelli & Gugerli, 2002) and NABERS (Love & Bullen, 2009). These two methodologies simplify users' choices in multi-disciplinarity problems associated to buildings refurbishment actions, measuring the influence of occupants' behaviour about the adaptation of abandoned sites. In addition, a performance-based planning approach is applied by Aigwi et al. (Aigwi et al. 2019; 2020) to set criteria and priority aspects affecting adaptive reuse models. This methodological application involves the promotion of strategic design guidelines and activities through the adoption of performance trends to develop effective outcomes (Frew et al., 2016) and improve collaborative decisions (Baker et al., 2006; Aigwi et al., 2019).

An effective tool in the construction field is the Analytic Hierarchy Process (AHP) (Saaty, 1980). Such multicriteria model is widely applied in the construction field to evaluate solutions and quantify design parameters. It is based on problem decomposition into independent parameters, analysing each criterion individually to the identification of priority vectors (Saaty & Vargas, 2001). However, this methodology is efficient for a limited number of independent parameters. To strengthen the consistency of AHP and extend the weighting procedure on a major number of independent indicators, Sangiorgio et al. (Sangiorgio et al., 2018a; 2018b; 2019) validate the Optimized Analytic Hierarchy Process (O-AHP). Such modern multi-attribute evaluation methodology is largely used in building engineering and in construction fields to manage complex problems when the decision maker does not have a full system knowledge.

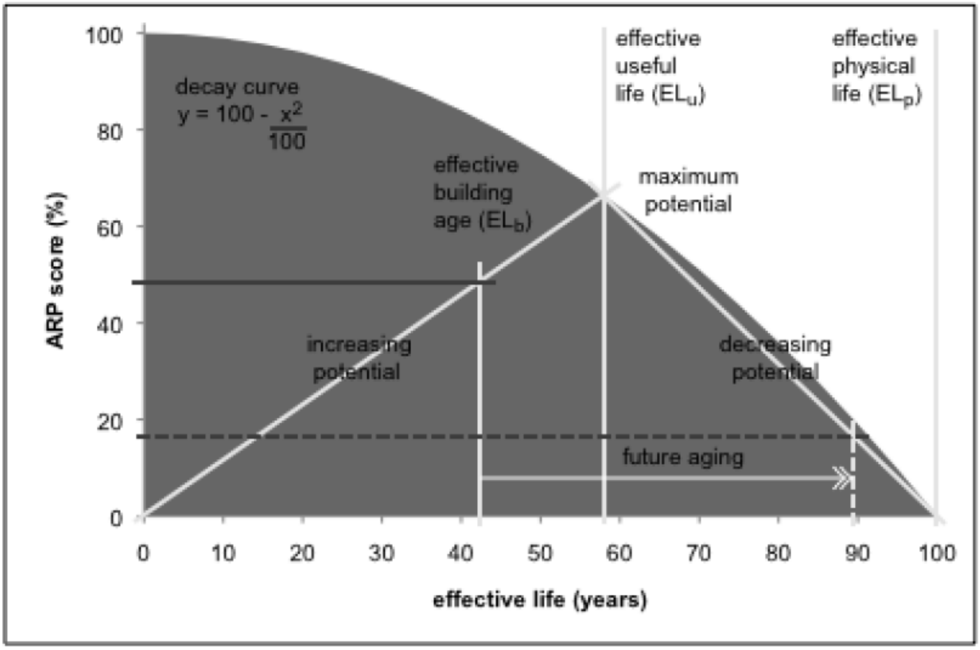
These multicriteria models and tools lead designers to understand the procedures to be carried out to choose the best strategies and feasible solutions for adaptive reuse processes, calculating buildings potentials of conversion, helping stakeholders' decisions in complex scenarios and activating achievable urban regeneration policies.

2.6.1 MCDM approaches for building potentials evaluation

Industries conversion approaches require the analysis of a wide spectrum of criteria. In addition, design factors influence the adaptation and transformations processes within the building envelope. Moreover, during refurbishment and planning phases, obstacles may occur. Therefore, the implementation of rules and strategies to manage adaptive reuse actions can facilitate stakeholders' choices about the design of feasible interventions. A type of multicriteria approach assesses the conversion potentials of an abandoned building, starting from the analysis of a set of obsolescence features. The results obtained from this analysis allow to understand if the building has the physical and spatial prerequisites to be transformed through adaptive reuse processes and the interventions of recovery and functional conversion ensure indoor comfort conditions, energy efficiency and environmental sustainability. In particular, the research focuses on two decision-making design methods widely used for the evaluation of adaptive reuse interventions of industrial sites: the ARP Model (Langston et al., 2008) and the AdaptSTAR Model (Conejos & Langston, 2010).

Based on Seeley's obsolescence factors (Physical, Economic, Functional, Social, Technological, Legal and Political) (Seeley, 1983), the ARP Model (Langston & Shen, 2007) weights each of these attributes to estimate adaptive reuse building potentials. The model classifies and ranks adaptive reuse intervention potentials of the existing construction stock, optimising collective social values and predicting future building redundancy (Langston, 2008; Langston et al., 2008). This model takes into account "useful life" parameter as a function of the physical building conditions and degree of obsolescence, allowing the estimation of building adaptability and the right timing for future interventions. In fact, ARP Model lists abandoned buildings according to the potential offered for the adaptive reuse transformation process at any point of time (Figure 2.6.1-1). The scheme identifies on the decay curve the point of building maximum potential use during its lifecycle, using the discounted physical life to determine the expected useful life in relation to the annual rate of obsolescence. The rate of discount is calculated as the sum of the obsolescence scores of each main criterion divided by the physical life. High obsolescence rates lead to lower useful life. Environmental context, occupational profile and structural integrity affect the estimation of building physical life. The model is widely applied to all countries and building typologies (Langston, 2008) and it has been validates using IconCUR multicriteria decision support system (Langston, 2012; Langston & Smith, 2012). ARP scores up to 50% present a high adaptive reuse potential. It means that building projects are feasible and functional to activate transformation processes and achieve economic, social and environmental benefits.

According to Langston's model, Sheila Conejos implements a new multicriteria evaluation application to rank adaptive reuse project (Conejos, 2013a; Conejos et al. 2013; Conejos et al., 2014; Conejos et al., 2015). Such model tries to translate Langston's ARP Model (Langston, 2008) into a set of planning procedures to describe future optimal building adaptation opportunities (Conejos & Langston, 2010).



$$\text{ARP (increasing)} = \frac{\left(100 - \frac{EL_u^2}{100}\right) \cdot EL_b}{EL_u} \qquad \text{ARP (decreasing)} = \frac{100 - \frac{EL_u^2}{100}}{100 - EL_u} \cdot (100 - EL_b)$$

Figure 2.6.1-1 The Adaptive Reuse Potential (ARP) Model concept (Langston et al., 2008).

The AdaptSTAR tool analyses the design strategies for building conversion activities, classifying criteria through a weighted checklist and calculating building adaptive re-use model efficiency. This decision-making application contributes the climate change adaptation for built assets (Conejos et al., 2015). The AdaptSTAR model scheme considers Seeley's seven categories of obsolescence (Seeley, 1983) and presents a hierarchical structure composed by categories and sub-categories and the relative weights (Figure 2.6.1-2). Each attribute and parameter are defined and insert in a structured interview to evaluate their importance in the design stage (Conejos, 2013b).

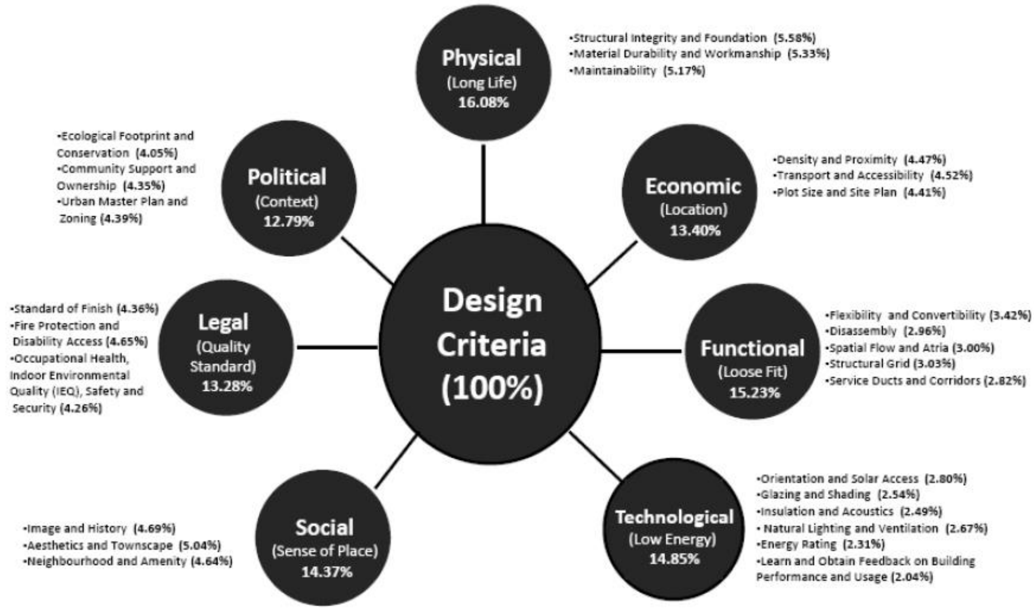


Figure 2.6.1-2 The AdaptSTAR Model concept (Conejos et al., 2015; Conejos et al., 2017).

Qualitative analyses allow researchers to fully understand the problems and parameters that affect the most adaptive reuse interventions, classifying them in each category of obsolescence. In addition, the star rating system calculates the project feasibility on the basis of the sum of criteria weights estimated by electronically structured interviews (Conejos & Langston, 2010). The performance of adaptive reuse design approach is scored considering weighted parameters used to calculate the total score

for future building conversion activities. The sensibility analysis, for measuring AdaptSTAR robustness, is made through the application of NVivo software (Conejos et al., 2015). It helps to organize, manage and measure the collected data, defining a series of strategies useful to develop construction transformations through adaptive reuse. The third and final step involves the comparison of the AdaptSTAR model with the Langston's ARP model. This modern tool is applied on Hong Kong (Conejos et al., 2017) and Australian (Conejos et al., 2011; Conejos et al., 2012) case studies. AdaptSTAR Model is applicable to existing building heritage, demonstrating the possibility to achieve building adaptivity also in complex situations.
These models facilitate the design procedures that can be carried out to select sustainable and efficient adaptive reuse solutions, calculating buildings potentials of conversion. Architects, engineers, urbanists and developers must understand the potential of context regeneration processes and industries adaptation interventions, satisfying social needs with new constructions, through the choice of appropriate sustainable technologies and functions.

2.6.2 MCDM approaches for buildings scenarios selection

Decision-making processes for the conversion of abandoned factories, especially in the context of cultural heritage, are affected by multiple attributes that must be evaluated to develop efficient adaptive reuse strategies (Mazzanti, 2002). Lots of MCDMA methods allow to compare alternative projects and heterogeneous design strategies to assess the best intervention for a specific case study.
In the field of building adaptation and construction interventions, two different multicriteria selection tools can be consider as feasible and efficient methodologies to evaluate multiple complex design scenarios: the Multi Attribute Value Theory (MAVT) (Keeney & Raiffa, 1976) and the Optimised Analytic Hierarchy Process (O-AHP) (Sangiorgio, 2018). The difference between these two types of multicriteria decision-making models lies in the number of parameters that each methodology can manage and analyse.

MAVT is a multicriteria analysis technique that consider a finite number of alternatives (maximum 8) evaluated considering conflicting stakeholders' objectives. Each objective is characterized by multiple attributes that measure building performances in relation to that specific item (Keeney & Raiffa, 1976). This ranking application, on the basis of quantitative and qualitative data, defines and lists independent criteria and parameters for measuring different design alternatives conversion attitude. In addition, the model allows to elicit value functions and attributes weights through interviews and surveys of professional figures (Montibeller & Franco, 2007; Montibeller & Yoshizaki, 2011). The weight assessment of each parameter is calculated using specific questionnaires related to the SWING Weight Method (Schuwirth et al., 2012). Experts specialized in different fields of architecture, engineering and urban planning evaluate individually the parameters identified in the analysis phase, with the aim of understanding which of these most affect the intervention of adaptive reuse according to the hypothesized functions and architectural options. Ferretti et al. (Ferretti et al., 2014) apply this evaluation model on real industrial buildings to understand the best solution for cultural and touristic purposes, explaining that multicriteria techniques not only rank multiple alternatives, but also stimulate stakeholders debate with the identification of constraints and better design alternatives (Schuwirth et al., 2012).
Following Saaty AHP mathematical formulation and methodology (Saaty, 1980; Saaty & Vargas, 2001), Sangiorgio et al. (Sangiorgio et al., 2018) develop an optimised version application to compare multiple criteria simultaneously. The O-AHP re-elaborates the main steps of the classical AHP to determine the new matrix of judgements for the weight parameters estimation (Sangiorgio, 2018). This innovative implementation of the classical AHP allows to amplify the number of 7 ± 2 alternatives for the pairwise comparisons, reaching consistent results. The O-AHP method is utilized in concomitance to Decision Support Systems (DSSs). In order to simplify stakeholders' design choices, identify building constraints and estimate performances, these multicriteria decision-making models represent powerful tools to acquire, manage and rank parameters in complex design contexts (Sangiorgio, 2018; Sangiorgio et al., 2018b). Such application is validated on real complex case studies monitoring. From the lit-

erature, the O-AHP results as an effective and efficient tool to classify risks, pathologies, performance and monitoring activities that may affect buildings structures (Sangiorgio, 2018; Sangiorgio et al., 2018b; Sangiorgio et al., 2019), easily extendable on urban scale analyses to assess climate impacts and large-scale management and monitoring of city vulnerable districts (Sangiorgio et al., 2018a; Sangiorgio et al., 2020). In particular, this modern multicriteria analysis methodology can be effective in identifying urban reuse design scenarios involving disused industrial sites composed of a large number of buildings and a high degree of complexity and by physical, functional and technological degradation, promoting feasible and green strategies for the recovery of abandoned marginal territories.

2.7 Research objectives

The analysis of the literature on adaptive reuse issues and multicriteria evaluation methods has revealed the lack of Decision Support Systems (DSSs). These cannot provide, at the preliminary building design stage, a general and intuitive framework of the temporal steps to convert or re-functionalize abandoned industrial buildings. In addition, the themes of the reuse and refurbishment of unused marginal industrial fabrics are actual and constantly evolving, but, at the same time, they do not account all types of industrial warehouses and factories as tangible opportunities to develop concepts of sustainable urban regeneration and smart cities development. Most of researches and articles in literature, in fact, focus the attention on the study of strategies for the recovery and enhancement of historical industrial contexts, without, at the same time, caring about the enormous potentials represented by the implementation of reuse interventions and transformations of contemporary abandoned sheds. These newly developed industrial areas characterise the current and peripheral production and commercial sectors of modern cities. Empty and dismissed warehouses and productive contexts represent a real opportunity to adopt policies for the reuse of existing, flexible and low-degraded volumes, structures and surfaces, hypothesising

new services and functions to satisfy population needs, in order to achieve urban regeneration and completion of fragmented peripheries.
It is, therefore, necessary to hypothesize a weighted and universal multicriteria system that can manage a huge amount of data and design factors that can be composed by an intuitive interface, easily used by stakeholders. The different categories composing the DCS not only report parameters related to the recovery, enhancement and monitoring of historical abandoned industrial sites, but also consider physical, technological and functional attributes related to building adaptation processes and architectural transformation of abandoned contemporary industrial realities, achieving social, environmental and economic sustainability issues.
The main theme of the doctoral thesis concerns the implementation of a multicriteria Design Criteria System (DCS) (Vizzarri & Fatiguso, 2019; Vizzarri, 2020; Vizzarri et al., 2020a; b; c) for the management, selection and identification of the factors that most affect adaptive reuse processes for the recovery and transformation of decommissioned historical and modern industrial warehouses. This multi-objective radio-centric model must be effective for evaluating adaptive reuse strategies on every existing industrial typology even if the case study presents high level of decay, missing parts and physical constraints. In particular, the research goal is to specify a multicriteria analysis model that allows stakeholders to evaluate, in the preliminary design phase, adaptive reuse intervention strategies through structured surveys and descriptive tables compilation. These tools help stakeholders to catalogue existing factories features and the future design guidelines that are to be pursued in relation to functional, physical and social aspects.
The DCS must be able to perform the following tasks: easily detection and selection of data; acquiring information on building decay and architectural features by the factory cataloguing sheet; individuation of parameters relationships and automatic structuring and evaluation of adaptive reuse strategies with a prioritization of the involved actions in different refurbishment intervention phases.
The classification and management of design factors in the seven main design categories, identified by the literature analysis, provides a scan of the areas and sub-

attributes that can intervene in building conversion activities. The DCS is designed as a large container of information related to physical, economic, functional, technological, social, legal and political connotations that can be considered in building transformation and punctual recovery processes of disused industrial sites. In addition, the model catalogues and quantifies risks weights. Hazards may arise before, during and after adaptive reuse activities, assessing any repercussions on the feasibility of each analysed scenario. This type of approach is innovative in the field of construction as it manages to control and catalogue a large number of design parameters and specific solutions of adaptive reuse interventions.
For the definition of the multicriteria model structure and the weights quantification of each parameter of the seven main categories, a considerable number of professional and specialized figures in the fields of recovery and construction are interviewed, having a real estimate about the influence of the each attribute, sub-category and conversion activity on industrial reuse interventions.
A preliminary information classification phase on existing buildings that require transformation interventions takes place by compiling descriptive tables that synthesise the main architectural, morphological and physical characteristics of decommissioned industrial sites. The cataloguing sheet contains parameters closely related to the criteria introduced in the DCS, allowing users to automate strategy selection processes by inserting input data. At the same time, the multi-attribute value model exploits the relationships between elements belonging to the same field or between different categories through an accurate causes and effects study generated by design activities that have greatest impacts on adaptive reuse processes.
This original decision-making model is supported by the application of state-of-the-art multicriteria evaluation systems for a previous ranking of alternatives in complex design situations. The Multi-Attribute Value Theory (MAVT) and the Optimised Analytic Hierarchy Process (O-AHP) work synergically with the DCS to obtain feasible scenarios to develop adaptive reuse conversion policies. In particular, these models are tested on five heritage factories and contemporary warehouses in Bari with different shape, architectural values, social priorities and functional solutions. They can resolve

problems related to design complexity, obtaining reliable weights for each feature and feasible strategies, assessing sustainability issues. In the field of building recovery and adaptation, different techniques are consequently applied for the implementation of reuse policies on disused industrial site in suburban areas. The methodology requires the application of multiple tools with regards to multicriteria analyses, statistical evaluation models, building engineering and architecture potentials estimation.

DCS outputs includes diagrams and schemes that show the adaptive reuse strategy and all the items involved in the process of conversion, distinguished for each main category and refurbishment design stage. The graphs describe the connections between the different elements considered for that scenario and temporarily scan the succession of activities in a hierarchical order. The actions succession starts taking into consideration general design criteria until the identification of specific items to be carried out in building adaptation processes. These visual-based outputs allow users to easily identify the correct development of the adaptive reuse strategy in every design step.

Moreover, to strength the DCS robustness, the final feasibility coefficient (f) for measuring the adaptive reuse strategy potential is compared with Adaptive Reuse Potential (ARP) and AdaptSTAR models scores. Risks weighting and listing process in concordance to the identification of cost ranges complete the quantitative parameters that occur for the evaluation of adaptive reuse project.

The research also considers objectives connected to the social sphere. The analysis of the literature has revealed opposing views on the theme of the reuse of disused industrial areas. The development of a Decision Support System (DSS) that quickly and effectively manages and quantifies preliminary intervention strategies on disused industrial buildings is proposed not to exclude a priori the possibility of recovering an abandoned factory by stakeholders, but for decreasing demolition and reconstruction activities. Professionals must be aware of the potential of urban reuse of abandoned industrial buildings. The DCS methodology can be a useful tool to reduce urban sprawl and fragmented design scenarios. Expanding the field of adaptive reuse strategies through the classification of design criteria and constraints, calculation of the feasibility coefficient (f) and risk entity (r) score and extrapolation of adaptive reuse strategies flowcharts can help stakeholders in the analysis of feasible alternatives to regenerate complex decommissioned industrial contexts.

The following sections of the thesis analyse respectively:

I) General methodology and framework of the main phases that characterise the DCS architecture and the Decision Support System (DSS) useful for the alternative selection process. In addition, this section describes in detail the different parts that structure the multicriteria choice selection model, as well as the relationships that take place between the seven main design criteria for assessing adaptive reuse interventions of historical and modern disused industrial buildings and parametric costs related to building conversion and new construction interventions;

II) Application of the DCS and Decision Support Systems (DSSs) on five real case studies. The industrial sites differ in size, level of obsolescence of the existing context and historical importance. In-depth descriptions and morphological analyses of the abandoned industrial areas in the metropolitan city of Bari and case studies intrinsic characteristics frame the benefits, constraints and risks arisen from functional conversion activities. S.W.O.T. analysis, building cataloguing and design alternatives ranking processes using MCDMA are implemented in this section. These procedures lay the foundations to improve adaptive reuse strategies, representing the input data of the DCS;

III) Explanation of the methodology automation for the selection of smart strategies based on input data. Graphical schematization of adaptive reuse strategies through the adoption of intuitive flowcharts on the basis of the design scenario identified by the decision-making models. Calculation of the adaptive reuse project feasibility coefficient (f), estimation of the intervention potential risk value (r) that can occur during design phases and preliminary estimation of adaptive reuse intervention costs on the basis of the discounted prices of the industrial building typologies.

3. A METHODOLOGICAL APPROACH TO ASSESS ADAPTIVE REUSE STRATEGIES FOR THE REFURBISHMENT OF MARGINAL DISUSED INDUSTRIAL CONTEXTS

3.1 Towards the selection of adaptive reuse strategies for the conversion of dismissed industrial factories

The analysis of the state-of-the-art strengthens the importance to improve adaptive reuse strategies and systems to convert decommissioned industrial marginal sites. The implementation of Multi-Criteria Decision-Making Analyses (MCDMA) models to facilitate the detection of feasible refurbishment solutions and the quantification of design factors is a key point within a structured and integrated process for building adaptation and reuse. An optimal management of criteria in a unique usable and intuitive application amplify the accuracy of adaptive reuse process, highlighting risks and criticalities that may occur during the monitoring, planning and construction phases. This issue originates from the complexity of adaptive reuse intervention, the consideration of fragmented and not detailed data that can influence factories adaptation policies and the difficulties arisen from an inefficient collaboration of stakeholders involved in the conversion processes due to their different design views and expectations. These circumstances do not favour the development of strategic intervention policies in terms of economic savings, sustainability and building performances, leading to the execution of incoherent and ineffective urban planning transformations. The formulation and evaluation of feasible conversion solutions of abandoned factories in

preliminary design stages can effectively facilitate stakeholders' choices in complex adaptive reuse contexts. In addition, the graphic visualization of adaptive reuse scenarios and factors relationships represents an efficient estimation method to measure building potentials and adaptiveness. Moreover, it still needs to include the quantification of parameters weights and structured cataloguing table to automate the strategy selection methodology.
This research is the result of a detailed investigation of criteria that may affect building refurbishment actions and decision support tools in order to configure a methodology for easily evaluate and show preliminary adaptive reuse alternatives for the transformation of industrial abandoned context, determining the requirements to overcome limits and constraints underlined from literature.

The general framework for the design of DCS architecture and the development of multicriteria decision-making evaluation methodology is switched into two main steps:

a) The first methodological approach consists in the identification and management of criteria, sub-criteria and activities with the definition of a well-structured diagram that can easily classify factors;
b) The second application involves the ranking of feasible transformation scenarios through a first analysis of industries main characteristics and a consequent formulation of Decision Support Systems for the weight evaluation of pre-defined parameters and assessment of solutions potentials score.

In particular, the procedures to perceive strategic adaptive reuse policies on dismissed warehouses are based on seven sequential tasks: i) a Data Collection Phase which regards a specific analysis on existing adaptive reuse projects and information storage; ii) a Data Acquisition Phase supported by cataloguing tables and histograms for data management and functional adaptive reuse trends reviews; iii) Scenarios Selection Phase through MCDMA to help stakeholders in complex design contexts; iv) Definition of DCS structure, layers, parameters weights and criteria causes and effects relations based on hierarchical and radio-centric parameter disposition; v) Adaptive Reuse Strategies Formulation Phase performed by automated correlation between input quantitative and qualitative data of building cataloguing sheet and DCS weighted criteria; vi) Calculation of preliminary building costs considering national and regional unit prices and vii) Validation Phase of output DCS feasibility scores through ARP and AdaptSTAR models. In addition, Figure 3.1-1 (Figure 3.1-1) synthesizes the main phases of the proposed methodology, as well as the decision-making tools used to perform efficient and robust scenarios selection classification and sustainable adaptive reuse projects.

The Data Collection Phase includes the examination and individuation of main features, activities and information applied in adaptive reuse approaches. In particular, this step takes into account four different types of data: a) previous detailed investigation from literature of the main criteria and parameters involved in construction and refurbishment fields; b) preliminary analysis and monitoring of research case studies to obtain a first overview of the selected sites; c) classification of international adaptive reuse example of abandoned heritage and modern sheds and d) definition of building adaptation design steps. Listing a large number of avant-garde examples regarding industrial refurbishment and architectural transformation actions allow the acquisition of qualitative and quantitative data, having a general inspection about the evolution of this contemporary approach. An accurate storage and classification of attributes and sub-attributes ensures to overcome constraints in terms of retrieving information by multiple sources, grouping them in a single and schematic model.

The Data Acquisition Phase is performed by the implementation of two descriptive tables: the building cataloguing sheet to gather physical, social and functional building characteristics; the building recovery table to manage features in monitoring, planning, construction and maintenance phases. The first document guarantees an optimal overview both of the existing site and structure conditions and of the hypothesised adaptation solution. Indeed, this informative sheet is made available to distinguish a preliminary set of parameters and components to activate strategies selection through DCS tool. The building recovery table is a schematic map for the management of DCS components into eight main design steps starting from the site analysis, monitoring and diagnostic activities to conclude with maintenance interventions after the introduction of adaptive reuse techniques. Results, deriving from the classification of international adaptive reuse examples of derelict warehouses, are also accounted in this section.

In the Scenarios Selection Phase, two different Decision Support Systems (DSSs) are implemented. The Multi-Attribute Value Theory (MAVT) is applied to rank solutions from a limited set of criteria. On the contrary, the Optimised Analytic Hierarchy Process (O-AHP) simplifies decisions in complex design situations that examine a high number of independent criteria. The use of the two multicriteria approaches is subject to the presence of discordant design solutions to be evaluated on the basis of preselected criteria that may differ to each context iconicity and factory intrinsic structural and architectural design typologies. In particular, preliminary collection activities contribute to identify key independent parameters and their value ranges, as well as interviews of professional figures specialized in the field of engineering, building refurbishment, architecture and urban planning are essential surveys to be carried out to increase the decision-making model consistency.

The data acquired from the collection phases compose the Design Criteria System (DCS) architecture. The fourth step of the methodology defines the multicriteria DCS structure for the implementation of adaptive reuse strategies. In particular, the information collected from the literature review are distinguished into seven main design categories. In addition, criteria are managed in five hierarchical layers that firstly highlights general features, placed in the center of the graph, and point out the specific activities that can support the adaptive reuse strategy in the marginal subcategories. Each component of the DCS is classified with an identity code and weighted with structured surveys filled by a large number of professional figures of the same research fields. Following this cataloguing method, the DCS can easily control and monitor data, implementing efficient and feasible strategy selection procedures. The interviews results are normalized multiplying different coefficient ranges for the sum of the respondents for each answer value (from 1=Very Low influence, to 5=Very

High influence on building design phases). The automation of adaptation policies requires the individuation of relationships between categories and sub-attributes. Starting from three main categories (Physical, Functional and Social Design Criteria) this research stage investigates the internal and external connections between components of the DCS in order to create an interactive net of subsequent and timely disposed refurbishment and transformation activities that intervene in each specific adaptation scenario. For instance, high level of decay of the existing structure affect costs, amplify the complexity of refurbishment activities and extend design and realization times, influencing a lot project efficacy.

The Adaptive Reuse Strategies Formulation Phase consists in the elicitation and design of feasible warehouses conversion policies on the basis of the eight refurbishment steps contained in the building recovery table. In fact, this diagram shows the DCS components characterising each strategy of intervention for the considered case study. Moreover, this section of the methodology requires the information listed in the cataloguing sheet. All the quantitative and qualitative data inserted in each single tab and part of the scheme represent the input main features of the DCS, providing an automatic selection process of the adaptive reuse strategy through elements cause-and-effect connections. The sum of each weight of selected criteria allows to calculate the feasibility coefficient of that specific building adaptation intervention. In addition, the last section of the cataloguing sheet reports constraints that may occur during building recovery processes. The final strategic graph shows the possible hazards that may arise during conversion processes and provides the evaluation of the risk entity of adaptive reuse projects that involve abandoned industrial sites.

Other quantitative measures are implemented for the evaluation of preliminary construction costs. This process is accomplished through the comparison of the adaptive reuse plan with unit prices of existing converted industrial sites. This phase is devoted to support stakeholders who require a first monetary estimation of the transformation activity to measure project economic feasibility. In order to measure the consistency and robustness of the DCS selection methodology and the multicriteria evaluation tool, a sensibility analysis is developed.

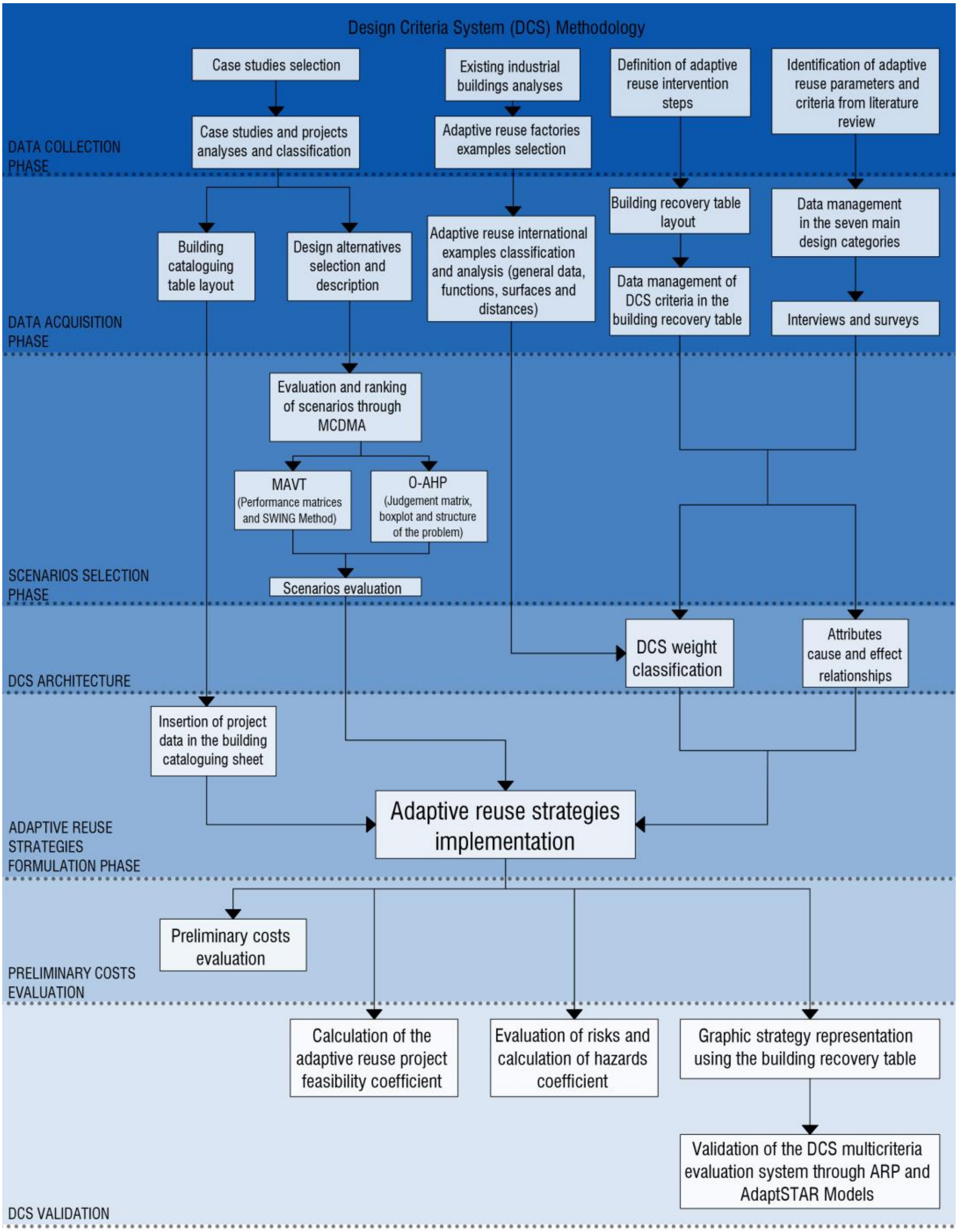


Figure 3.1-1 Main phases of the DCS Methodology for the evaluation of adaptive reuse strategies of abandoned industrial contexts.

The DCS feasibility coefficient is compared with ARP and AdaptSTAR scores. These two applications allow to measure building adaptive reuse potentials, considering seven categories of obsolescence, useful existing building life, physical life and accurate site monitoring analyses and architectural features descriptions. The correlation of these three multicriteria evaluation methods provide an intuitive and easy formulation ad estimation of adaptive reuse interventions on dismissed sheds.

3.2 The data collection phase

This first section of the methodology provides the identification, selection and conservation of factors, criteria and activities that are most involved in the processes of refurbishment and re-functionalization of abandoned heritage industrial buildings and disused suburban sheds. A previous revision of the literature, explained in the state-of-the-art, highlights the main categories that affect the building adaptation processes and the possible risks that may arise from refurbishment and transformation interventions. In addition, starting from the database of design criteria and parameters obtained from the literature review, three other different types of analyses are carried out: i) an extensive classification of international examples of industrial building reuse to identify the places where these conversion policies of urban voids are frequently adopted; (ii) a thorough study of the local territory and case studies monitoring to assess the morphological and architectural characteristics of abandoned factories and their level of degradation; (iii) a careful detection and framework of the main design step of building adaptation interventions. The Data Collection Phase considers the basic knowledge to investigate adaptive reuse policies of dismissed warehouses.

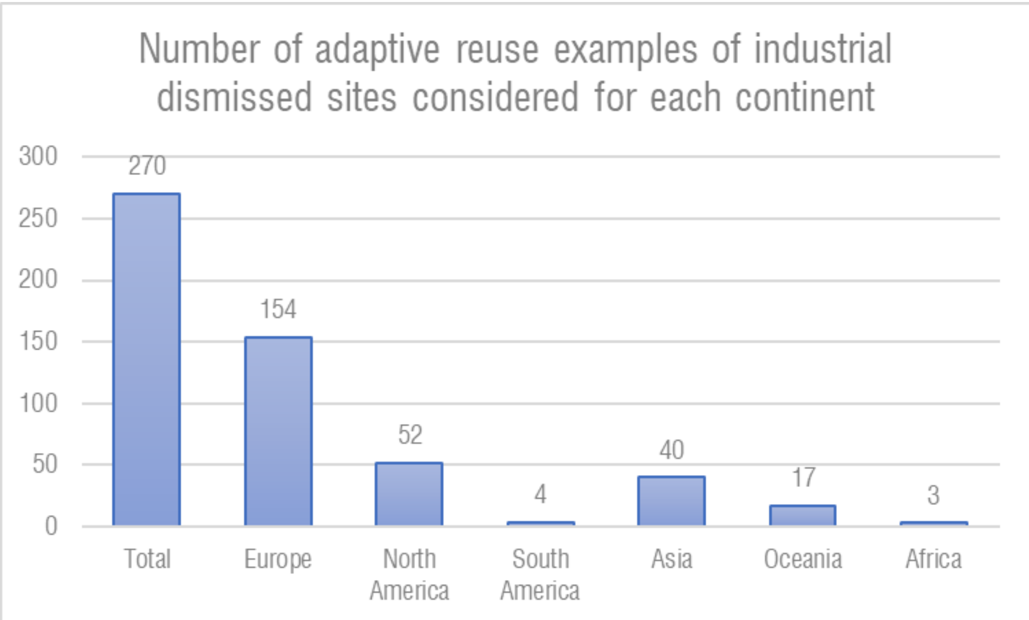
3.2.1 Identification and analysis of worldwide adaptive reuse examples of former industrial sites

The first method of collecting data regards the classification and description of worldwide adaptive reuse conversion scenarios of former heritage and modern industrial derelict sites. A list of 270 existing international dismissed factories refurbishment master plan in 36 different nations provides morphological and functional information of the adaptive reuse projects (ANNEX A). In particular, this descriptive table outlines, in the initial sections, general data that identify sites names, locations, years of the adaptive reuse conversion processes and architectural studios and building companies involved in the realization of each plan. In addition, the register differentiates case studies by country. Each nation, in fact, is classified with an identification code number that facilitates and speeds up the classification of buildings (Table 3.2.1-1).

NATION	ID CODE	NATION	ID CODE
USA	1	SPAIN	19
DENMARK	2	SWEDEN	20
ITALY	3	BRASIL	21
SWITZERLAND	4	SOUTH AFRICA	22
CANADA	5	BELGIUM	23
POLAND	6	FINLAND	24
NEW ZEALAND	7	RUSSIA	25
THAILAND	8	GERMANY	26
AUSTRALIA	9	SINGAPORE	27
FRANCE	10	AUSTRIA	28
ARGENTINA	11	ICELAND	29
CHINA	12	NORWAY	30
INDIA	13	PORTUGAL	31
JAPAN	14	HUNGARY	32
THE NETHERLANDS	15	LUXEMBOURG	33
ESTONIA	16	CYPRUS	34
CZECH REPUBLIC	17	MEXICO	35
GREAT BRITAIN	18	SOUTH KOREA	36

Table 3.2.1-1 Nations classification through ID codes.

Tables 3.2.1-2 and 3.2.1-3 (Tables 3.2.1-2; 3) show the number of warehouses analysed for each continent and country. The two graphs illustrate a prevalence of adaptive reuse activities of abandoned warehouses especially in Europe (Italy, Germany, Great Britain, France, Belgium and the Netherlands) (154 examples), North America (USA) (52 examples) and Asia (China, Singapore and Japan) (40 examples). The presence in these areas of a large number of reuse interventions on disused factories is closely related to their historical and evolutionary connotation. For instance, Europe is characterised by cities and industrial regions that marked the period of the Industrial Revolution and standardised mass production. At the same time, nowadays, the advent of the tertiary sector has led to the abandonment of historic industrial sites and the adoption by institutions of innovative and sustainable reuse measures to develop new inclusive policies of these empty spaces within the city context with the aims of meeting the contemporary needs of society and attempting to reduce phenomena of urban sprawl.



%	100	**57.04**	**19.26**	1.48	**14.81**	6.30	1.11

Table 3.2.1-2 Number of adaptive reuse interventions on disused factories in each continent.

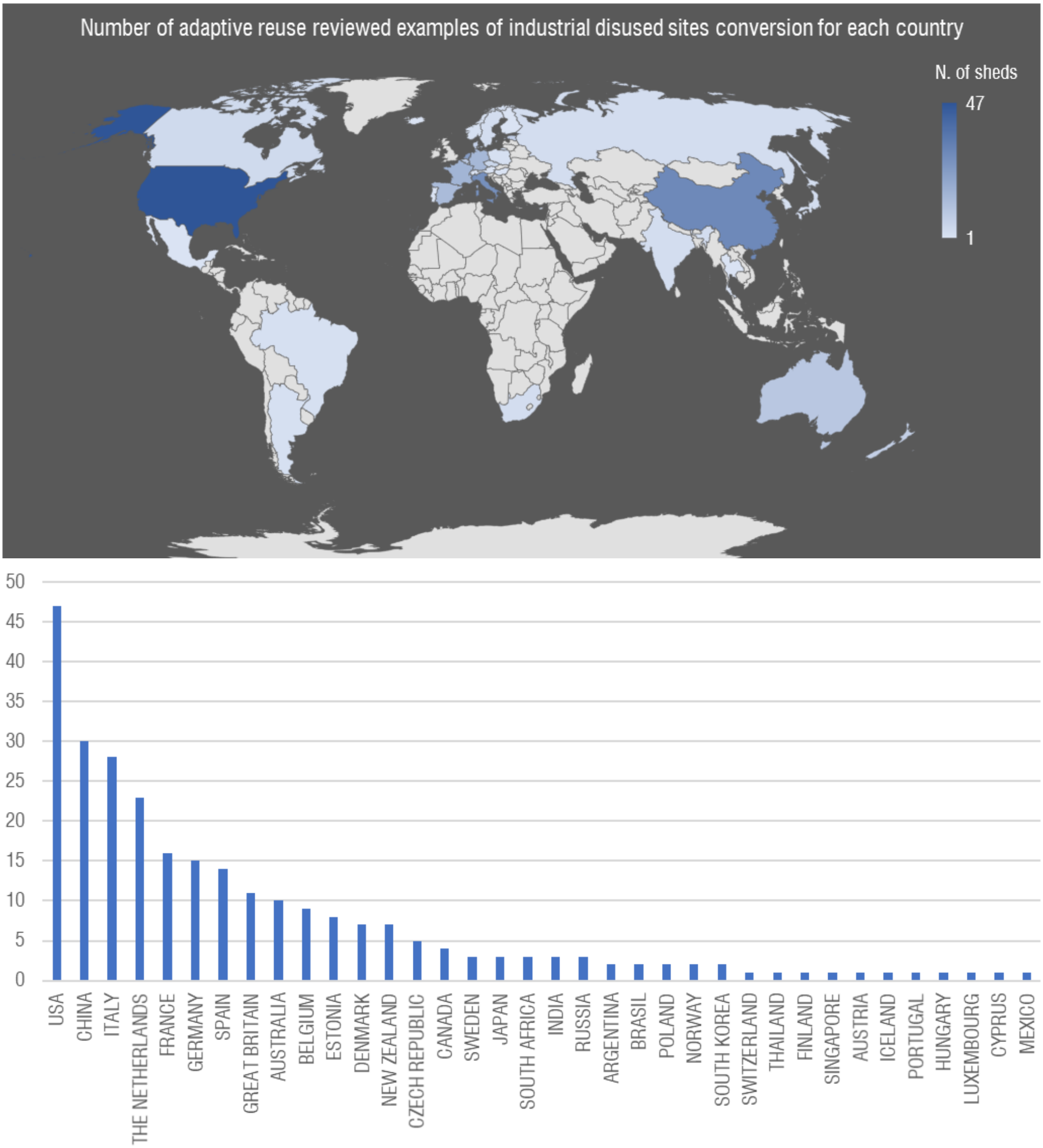


Table 3.2.1-3 Number of adaptive reuse interventions on disused factories in each country.

The second part of the descriptive table contains quantitative and qualitative data concerning the historical importance of the context, the distance of each building from the city center, the total area of the lot and the main functions inserted after the intervention of adaptive reuse. A fundamental stat derives from the analysis of historic (S) and not historic (NS) industrial sites. Out of a total of 270 re-functionalized industrial sites, 166 of them (61.48%) present historical architectural values to preserve and enhance, as well as compositional and material characteristics typical of the technologies and industrial planning of the late nineteenth and early twentieth centuries. The remaining 104 examples of adaptive reuse concern modern disused warehouses that do not incorporate valuable design and stylistic design components (38.52%) (Table 3.2.1-4). In particular, the percentage of not historic factories is significant to understand how the implementation of adaptive reuse strategies is not only aimed at restoring the architectural and cultural values of heritage industrial buildings, but also involves all the urban volumes and dismissed surfaces of the modern expansion productive and commercial areas that have suffered the repercussions of the economic crisis of recent years. This marked change in the promotion of building adaptation policies for existing abandoned sheds is based on a renewed interest of stakeholders and national and regional institutions towards the reuse of these industrial wrecks to implement feasible sustainable and strategic cities development actions and effective projects for urban regeneration of suburbs.

	Number of sites	**%**
Historical (S)	166	61.48
Not Historical (NS)	104	38.52
Total	270	100

Table 3.2.1-4 Historic and not historic industrial sites classification.

3.2.2 Case study analysis

The analysis of case studies allows to collect data on the geometric, typological and construction components of abandoned industrial buildings in the metropolitan area of Bari. An active survey and continuous monitoring of the accounted disused industrial buildings provide to define a detailed framework of its structural, architectural components and evolution over time and the surrounding context. A constant

view and visiting action of these empty volumes helps to develop a wide knowledge system that contributes to evaluate a multiplicity of data, identifying actual site benefits and problems. In addition, the consultation of maps, plants and sections related to the different areas studied facilitates the understanding of the interior spaces of each volume, as well as the identification of constraints and risks. Indeed, the design of 3D models using graphics software (Rhinoceros, V-Ray and AutoCad) provides an overall dynamic view of the disused existing buildings within each industrial site considered. The analysis of existing spaces is not only limited to the study within the boundaries of the disused industrial area, but also encompasses all the fabric surrounding the lot. In particular, the characterization of the context, in which the abandoned industrial areas reside, takes place through the use of thematic conceptual maps that evaluate, on the basis of regional and municipal regulations and planning documents, Bari's industrial districts. These graphic and intuitive posters concerns the morphological and functional layout of the territory, soil characteristics and consistency, hydro-geomorphological risks, greenery and public space systems, hierarchization of roads, rail and aerial connections, factories and buildings heights, identification of active or abandoned industrial sites and typological analysis of warehouses divided by year of construction and extension.
All this information facilitates the selection of activities that can be functional for future building recovery interventions.

3.2.3 Definition of building reuse design steps

The third type of analysis that makes up the research refers to the identification of the main design steps to be considered for building refurbishment and adaptation interventions.
The study of the activities involved in the building life cycle and conversion processes allows to outline eight sequential and temporal planning steps that specify, in the preliminary design phase, the development order of adaptive reuse policies (Table 3.2.3-1). In particular, the transformation process of disused industrial warehouses defines

the procedural apparatus that may be able to organize and frame the categories, macro-scopes and micro-scopes that influence building adaptation actions.
The structuring of an integrated system of closely related and linked interventions and refurbishment actions favours the implementation of effective reuse strategies, developing a conceptual and temporal work breakdown structure of adaptive reuse design activities and a unified vision of the main operations that stakeholders must apply to carry out innovative and sustainable planning policies for the conservation and enhancement of abandoned marginal industrial fabrics.

Building adaptive reuse design steps	*Description of the intervention*
1. Evaluation ex-ante and site monitoring and survey	Includes all monitoring, site surveys and diagnosis activities to be carried out before the start of the organization, design and implementation phases concerning the adaptive reuse intervention. This first on-site activity assesses the level of degradation of context features and existing structures characterising the disused industrial site, as well as risks and problems already present or that may arise during building refunctionalization processes. Neighbourhood social analyses specify the current needs of the population to be met in the adaptive reuse project.
2. Programming activities for building recovery and transformation	It identifies and organizes the activities of recovery and transformation of the building through the collaboration of multiple specialized figures. The design of work breakdown structures and GANTT diagrams ensures a better visualization of planning purposes and the succession of activities. In this phase, project partners are also identified, as well as relationships with private investors and public administrations to obtain funds for plan design, development and implementation.
3. Master plan conception (project of external areas and landmarks)	It provides the elaboration of a logical framework that guarantees a complete view of the main components and features of the new design idea, focusing on the design of the external areas and identifying landmarks of the transformed industri-

	al site. This phase involves the active participation not only of architects, engineers and urban planners, but also of the citizens who live in the neighbourhood, in order to outline targeted intervention strategies to improve the life quality, social sense of place, security and safety.
4. Design of the adaptive reuse intervention (hypothesis of building refurbishment and conversion actions)	This step considers all the design activities of adaptive reuse interventions for the recovery and enhancement of disused industrial sites. The intervention scenarios can involve the formal, technological, material and architectural aspects of the building and the interior empty and abandoned warehouses spaces. In this phase, a detailed description of the adaptive reuse project is elaborated with the specification of methods of intervention and an accurate and detailed documentation necessary for its approval.
5. Plan approval	Preliminary, executive and final approval of the adaptive reuse project. This step is closely connected with the previous one, as the refurbishment and renewal solution is analysed by municipal authorities competent in the field of architectural design and spatial planning and evaluated on the basis of consistency with current regulations and laws. The duration of this operation is variable and depends on the approval procedures adopted and the presence or not of project design changes and/or economic budget alterations.
6. Implementation of recovery and reuse interventions on the existing structure and realisation of new buildings	Implementation and realization of the adaptive reuse interventions, starting from the recovery activities of the existing structures up to the introduction and construction of new volumes and architectural, technological and spatial innovative solutions that amplify site attractiveness and iconicity. At this stage, building adaptive reuse and transformation activities require the mobilization of all the necessary human and mechanical resources. The development of accurate and constant control and management of project works provides a comparison of the activities carried out with respect to the approved docu-

	mentation, identifying any planning distortions and shortcomings that can compromise the effectiveness of the intervention.
7. Evaluation of building quality (safety and security) and community spatial usability	Final evaluation of the reuse intervention through the check of the expected results and the testing of building quality in terms of indoor comfort, energy performances, people safety and protection devices, spaces usability and flexibility, satisfying population needs.
8. Evaluation ex-post and maintenance activities	Evaluation of adaptive reuse intervention over time. The monitoring ex-post activity depends on the complexity of the adaptive reuse conversion. The organization and planning of periodic control surveys of structural, technological, plant and material components, as well as ordinary and extraordinary maintenance interventions.

Table 3.2.3-1 Eight design principal steps for the implementation of adaptive reuse interventions in urban complex scenarios.

3.3 The data acquisition phase

The second step of the proposed methodology manages and organises all the data gathered in the Data Collection Phase in schematic table sheets. The information about all the factors involved in the building reconversion process are stored and organized in summary tables, guaranteeing an optimum data management and an intuitive classification of adaptive reuse components. In particular, attributes and sub-attributes are sorted into the seven main adaptive reuse design categories highlighted in the literature review process (Langston et al., 2007; Langston, 2008; Langston, 2011; Conejos & Langston, 2010; Conejos et al., 2011; 2013; Conejos, 2013a; 2013b; Mohamed & Alauddin, 2016), characterising the DCS hierarchical structure. In addition, the information related to site survey activities, building constant monitoring, project architectural, functional and technological alternatives and adaptive reuse worldwide examples allow to: i) fill in the cataloguing table sheet for a detailed description of the factories existing conditions and future interventions, considering functional, physical and social parameters; ii) accurately classify the design criteria, attributes, sub-attributes and activities in the building recovery table, managing components in the eight reuse design steps and iii) extrapolate from the adaptive reuse international plans analysis table intelligible histograms and toolbars, distinguishing site surfaces, distances from the city centre and functional adaptation trends. These cataloguing methods provide a general overview of the building adaptation topics examined in the state-of-the-art and descriptive and graphic schemes easily understandable and usable by stakeholders in complex decision-making contexts.

3.3.1 The building cataloguing sheet

A first cataloguing activity of existing industrial building main features and design parameters evaluation of the hypothesised adaptive reuse scenarios for the improvement of urban regeneration processes on marginal contexts are traced back to the compilation of descriptive tables.
The building cataloguing sheet, in fact, provides a first identikit of the case study, managing information to describe morphological, constructive and architectural values and obsolescence of the existing layout. In addition, this table includes photographs of the site, S.W.O.T. analysis, hazards and constraints and social, functional and physical design data. The main objective of the module is to retrieve, store and combine all the data regarding building adaptation interventions and make it available for the subsequent interpolation with the DCS.

In particular, the cataloguing tab is composed by six different subsections:

a) General building data, containing photos, geographical and morphological information, years of construction and decommission, total built volume, surfaces, building heights and number of floors, number of existing structures and maintainability issues (Table 3.3.1-1);

b) Physical building data are divided into three sections. The first part analyses the level of decay of each building component, as well as site conditions in terms of pollution, urban and environmental features (Table 3.3.1-2a). The last two sections focus the attention on formal, architectural and stylistic criteria that the new adaptive reuse solution implement (Table 3.3.1-2b). Quantitative spatial data regarding the new envelope introduced in the master plan complete this tab;

c) Functional analysis describes the main and specific functions hypothesised in the conversion strategy. It also provides the evaluation of site distances, connectivity and flexibility (Table 3.3.1-3);

d) Social analysis outlines stakeholders and users involved in the transformation processes, as well as lists population needs and people sense of place attributes (Table 3.3.1-4);

e) Other information considers materials, technologies and feasibility evaluation of the adaptive reuse intervention (Table 3.3.1-5);

f) S.W.O.T. analysis and risks detection allow to specify building potentials and its possible reuse interventions. The S.W.O.T. method is a strategic and analytic tool for assessing strengths and weaknesses of an existing building, describing possible transformation and refurbishment opportunities, as well as, threats faced by the conversion activities (Table 3.3.1-6).

The registry tab represents a first tool to assess adaptive reuse processes, cause its data are considered in the DCS as input criteria. In addition, this module promotes the development of dismissed factories classification models, guaranteeing a detailed knowledge of investigating industrial contexts.

Industrial site aerial photography					
General Data					
Building/site name			Climatic zone		
City			Orientation		
Region			Number of entrances		
Nation			Landscape quality	*high/medium/low*	
Address			Building Size	*very small/small/medium/big/very big*	
Site location			Site surface (m²)		
Years of construction and dismission			Building surface (m²)		
Distance from city center			Total volume (m³)		
Number of existing buildings			Level of maintainablity	Site =*high/medium/low*	
Number of historic buildings				Context =*high/medium/low*	
Building structural typology				Infrastructures =*high/medium/low*	
Green areas (m²)			Reclamation interventions	*Yes/no*	
Public space (m²)			Glazed surface	*high/medium/low*	
Existing buildings data					
Building Surfaces (m²)	Building 1		Volumes (m³)	Building 1	
	Building 2			Building 2	
	Building 3			Building 3	
Heights (m)	Building 1		Number of floors	Building 1	
	Building 2			Building 2	
	Building 3			Building 3	

Table 3.3.1-1 Building Cataloguing Sheet: General Data.

Physical analysis					
Existing abandoned industrial site					
Level of decay	Site	*high/medium/low*	Dampness	*high/medium/low*	Presence of constraints
	Buildings	*high/medium/low*	Pests	*high/medium/low*	
	Materials	*high/medium/low*	Natural attack	*high/medium/low*	
	Structures	Pillars =*high/medium/low*	Existing plants		
		Beams =*high/medium/low*			
		Walls =*high/medium/low*			
		Vertical connections =*high/medium/low*			
		Foundation =*high/medium/low*	Site conditions	Soil type	
		Floor =*high/medium/low*		Presence of vegetation	*high/medium/low*
		Roof =*high/medium/low*		Level of traffic	Car =*high/medium/low*
		Joints =*high/medium/low*			Bike =*high/medium/low*
		Facade =*high/medium/low*			Bus =*high/medium/low*
	Plants	*high/medium/low*			Camion =*high/medium/low*
	Technologies	*high/medium/low*			Train =*high/medium/low*
	Functional decay	Parking areas =*high/medium/low*			Pedestrian =*high/medium/low*
		Space dimensions =*high/medium/low*			Other ….
		Flows management =*high/medium/low*		Level of pollution	Environmental=*high/medium/low*
	Green areas	*high/medium/low*			Acoustic=*high/medium/low*
	Context	*high/medium/low*			Water=*high/medium/low*
Level of humidity	*high/medium/low*				Soil=*high/medium/low*
Presence of asbestos	*high/medium/low*				Light=*high/medium/low*
Lack of building parts	*high/medium/low*				Air=*high/medium/low*

Table 3.3.1-2a Building Cataloguing Sheet: Physical Analysis (Existing abandoned industrial site).

Project					
Buildign transformation interventions	Cladding	*Yes/no*		Subtraction	*Yes/no*
	Interior design	*Yes/no*		Demolition	*Yes/no*
	Addition	Connection	*Yes/no*	Envolve	*Yes/no*
		Merge	*Yes/no*	Outside	*Yes/no*
		Elevation	*Yes/no*	Connection through public space	*Yes/no*
		Intrusion	*Yes/no*	Landscape and urban art	*Yes/no*
		Stack	*Yes/no*		
		Duplication	*Yes/no*	Excavation	*Yes/no*
N. of new buildings			M² added surfaces		
N. of refurbished buildings			M³ added volumes		
N. of demolished buildings			Insertion of new openings	*Yes/no*	
New buildings project data					
Building Surfaces (m²)	Building 1		Volumes (m³)	Building 1	
	Building 2			Building 2	
	Building 3			Building 3	
Heights (m)	Building 1		Number of floors	Building 1	
	Building 2			Building 2	
	Building 3			Building 3	

Table 3.3.1-2b Building Cataloguing Sheet: Physical Analysis (Adaptive Reuse project).

Functional analysis		
Space flexibility and convertibility	*high/medium/low*	*high/medium/low*
Main functions	Function category	Specific function
N. of services		
Level of accessibility and connectivity	*high/medium/low*	*high/medium/low*
Spatial flow management	*high/medium/low*	
Dismantlability	*high/medium/low*	
Project building total surface (m²)		
Project green areas (m²)		
Project public spaces (m²)		
Distance from points of interest	Points of interest	Distance (Km)
Building connectivity	Points of interest	*high/medium/low*
	Parking areas, public spaces and green areas	*high/medium/low*
	City centre	*high/medium/low*
	Waterfront	*high/medium/low*
	Main services	*high/medium/low*

Table 3.3.1-3 Building Cataloguing Sheet: Functional Analysis.

Social analysis	
Stakeholders involved	
Users	
Population needs	
Site importance for society	high/medium/low
Usability and liveability	high/medium/low
Site aesthetic identity	high/medium/low
Site attractiveness	high/medium/low
Relation society-environment-building	high/medium/low
Social inclusion	high/medium/low
Social participation	high/medium/low

Table 3.3.1-4 Building Cataloguing Sheet: Social Analysis.

Other information					
Economic feasibility	*high/medium/low*	Political feasibility	*high/medium/low*	Investments	*high/medium/low and public/private*
Applied materials		Implemented technologies		Security and safety systems	

Table 3.3.1-5 Building Cataloguing Sheet: Other Information.

S.W.O.T. Analysis	
Strenghts	**Weaknesses**
Opportunities	**Threats**
Risks	

Table 3.3.1-6 Building Cataloguing Sheet: S.W.O.T. Analysis and Risks.

3.3.2 The building recovery table

The temporal management of adaptive reuse criteria and the visualization of transformation strategies are included in the building recovery table. It provides to displace attributes and sub-attributes in eight design steps of interventions, described in the previous section. In particular, the module is composed by eight columns that represent the design phases and seven stripes according to the main adaptive reuse categories reviewed in the state-of-the-art (Table 3.3.2-1). Such scheme shows the relationships between DCS components and represent the tool that allows stakeholders to easily comprehend adaptive reuse strategies evolution and labels interactions and successions.

The building recovery table aims to graphically transfer the succession of selected DCS elements for a given adaptive reuse scenario of disused industrial buildings. This approach allows professionals to arrange a user-friendly tool that pre-examines the individual elements that may intervene in the building design, implementation and monitoring refurbishment and conversion activities. In addition, the uniqueness of the building recovery table resides in its interesting, simple and manageable layout. It distinguishes criteria vertically in the seven main design factors and scans them horizontally according to the eight phases that characterize this modern and sustainable industrial redevelopment approach. These data correspond to the output information of DCS for each conversion strategy adopted on industrial case studies.

	Evaluation ex-ante and site monitoring and survey	Programming activities for building recovery and transformation	Masterplan conception (project of ex-ternal areas and landmarks)	Design of the adaptive reuse intervention (hypothesis of building refurbishment and conversion actions)	Plan approval	Implementation of recovery and reuse interventions on the existing structure and realisation of new buildings	Evaluation of building quality (safety and security) and community spatial usability	Evaluation ex-post and activation of management and ordinary and extraordinary maintenance activities
Physical Design Criteria								
Economic Design Criteria								
Functional Design Criteria								
Technological Design Criteria								
Social Design Criteria								
Legal Design Criteria								
Political Design Criteria								

Table 3.3.2-1 Building Recovery Table layout.

3.3.3 Functional conversion trends and spatial-dimensional analysis of adaptive re-use interventions on abandoned sheds

The second part of the building adaptive reuse international examples table provides the cataloguing of spatial-dimensional and functional data, considering the warehouses distances from the city center, industrial sites surfaces and functional programs implemented in the refurbishment projects. This section highlights the functional trends that stakeholders and designers adopt most in the building transformation processes of disused industrial sites. In addition, the examples classification tool enables to relate dimensional information about the extension of industrial adaptive reuse projects with their localization in the urban context, with the aim of understanding which parts of cities are most affected by this modern type of building regeneration intervention. All these data are resumed in the general adaptive reuse tab (ANNEX A). In particular, three different methods of analysis have been adopted:

A) Functional analysis includes information about the services that compose each adaptation project. It distinguishes project activities in eleven functional scopes (Cultural, Residential, Religious, Commercial, Offices, Sporty, Education, Relax & Fun, Public spaces, Healthcare and Children areas), highlighted in the state-of-the-art, evaluating the number of reuse examples for each task. These functions are also implemented in the DCS in the Functional Design Criteria main category. Such study outlines interesting output data about the services most required by stakeholders and users. As shown in Figure 3.3.3-1 (Figure 3.3.3-1), the main functions considered in the adaptive reuse processes of dismissed industrial contexts regards cultural (138 examples; 21.84%), offices (128 examples; 20.25%), commercial (89 examples; 14.08%) and public space (88 examples; 13.92%) attributes.

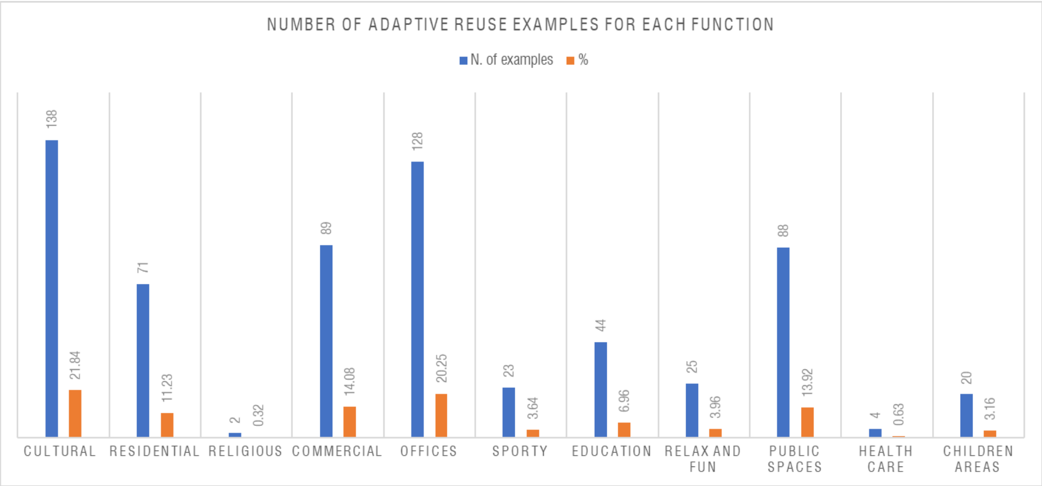


Figure 3.3.3-1 Functional analysis output data.

These functional solutions encourage sustainable policies for the renewal of existing industrial structures, increasing the quality of life, job opportunities, attractiveness of places and social interactions between neighbourhoods and introducing new cultural point of interest, commercial spaces and green areas useful for the development of the city's suburbs.

B) Site location analysis provides an exhaustive description of the adaptive reuse projects distances from the city center. This method divides the industrial refurbishment worldwide example in three ranges: i) short distance ($x \leq 3Km$); ii) medium distance ($3Km < x \leq 8Km$) and iii) high distance ($x > 8Km$). The outputs of Figure 3.3.3-2 (Figure 3.3.3-2) explains that a large number of the selected examples is located in a medium-high range from the city center (174 examples in total; 64.4%). Distance quantitative data are fundamental to understand the punctual recovery and enhancement strategies adopted in the different urban contexts. The presence of a considerable number of industrial buildings arranged in an intermediate distance from the main points of interest strengthens the effectiveness of adaptive reuse interventions on marginal abandoned industrial buildings contexts, promoting sustainable urban regeneration policies.

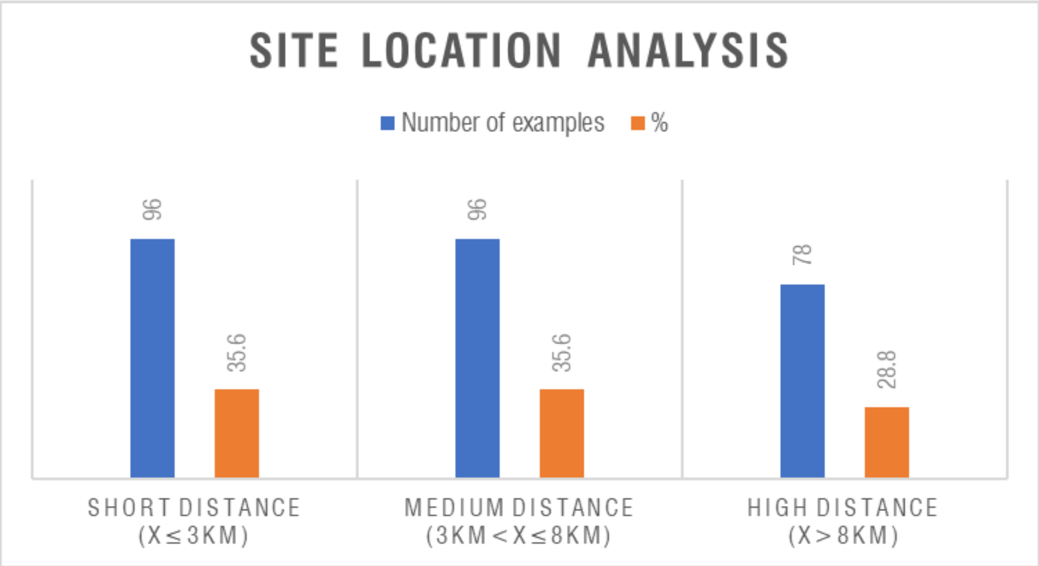


Figure 3.3.3-2 Site location analysis output data.

C) Building spatial analysis lists adaptive reuse examples surfaces stats. Projects are classified into three different dimensional ranges: small size surface (y≤1000sqm); medium size surface (1000sqm<y≤5000sqm) and big size surface (y>5000sqm). This survey highlights that the majority of the refurbishment interventions are applied on medium and big size warehouses (228 examples in total; 84.1%) (Figure 3.3.3-3), due to their high level of flexibility and adaptation potentials. In addition, the refurbishment of large site surfaces allows to insert multiple functions, satisfying population needs and, at the same time, re-aggregates fragmented districts with innovative solutions, transforming industrial voids into opportunities for cities development.

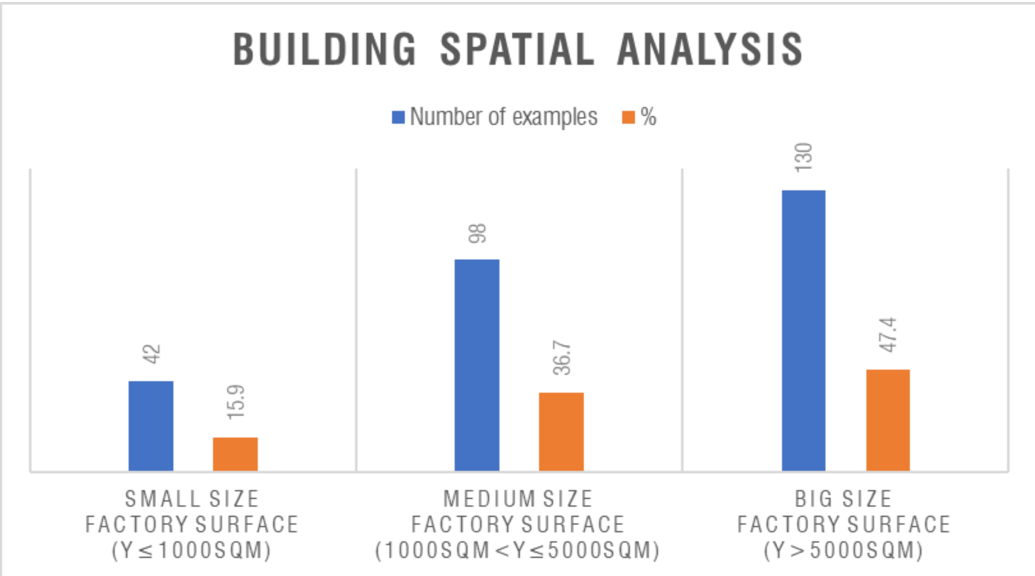


Figure 3.3.3-3 Building spatial analysis output data.

The interpolation of spatial distances and dimensional assets in unique and biaxial histograms can easily compare the two analyses in order to enhance knowledge about the evolution of adaptive reuse policies on international former industrial contexts, identifying the cities tissues most involved in these processes (Figure 3.3.3-4a; 4b).

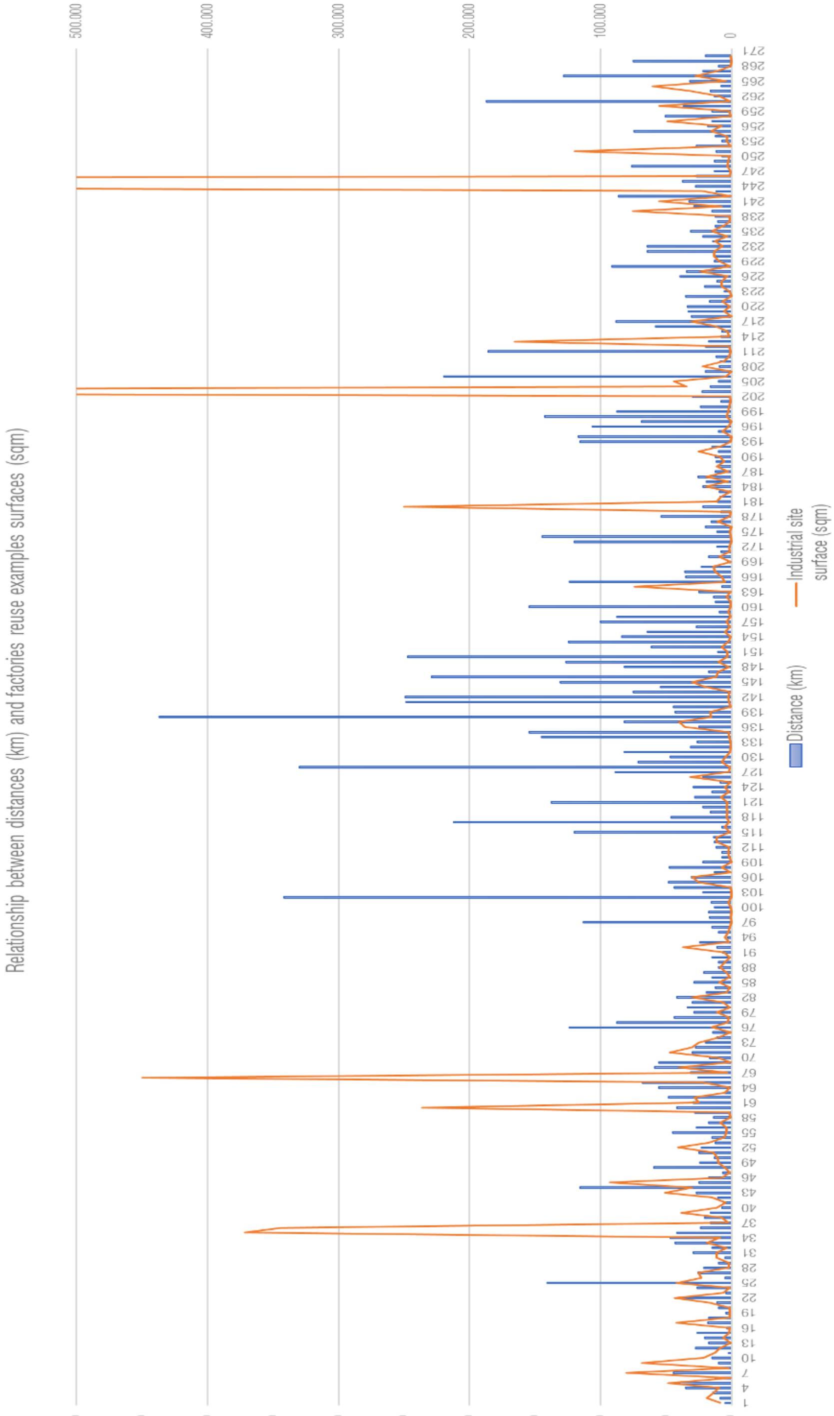


Figure 3.3.3-4a Comparison of dimensional and spatial output data.

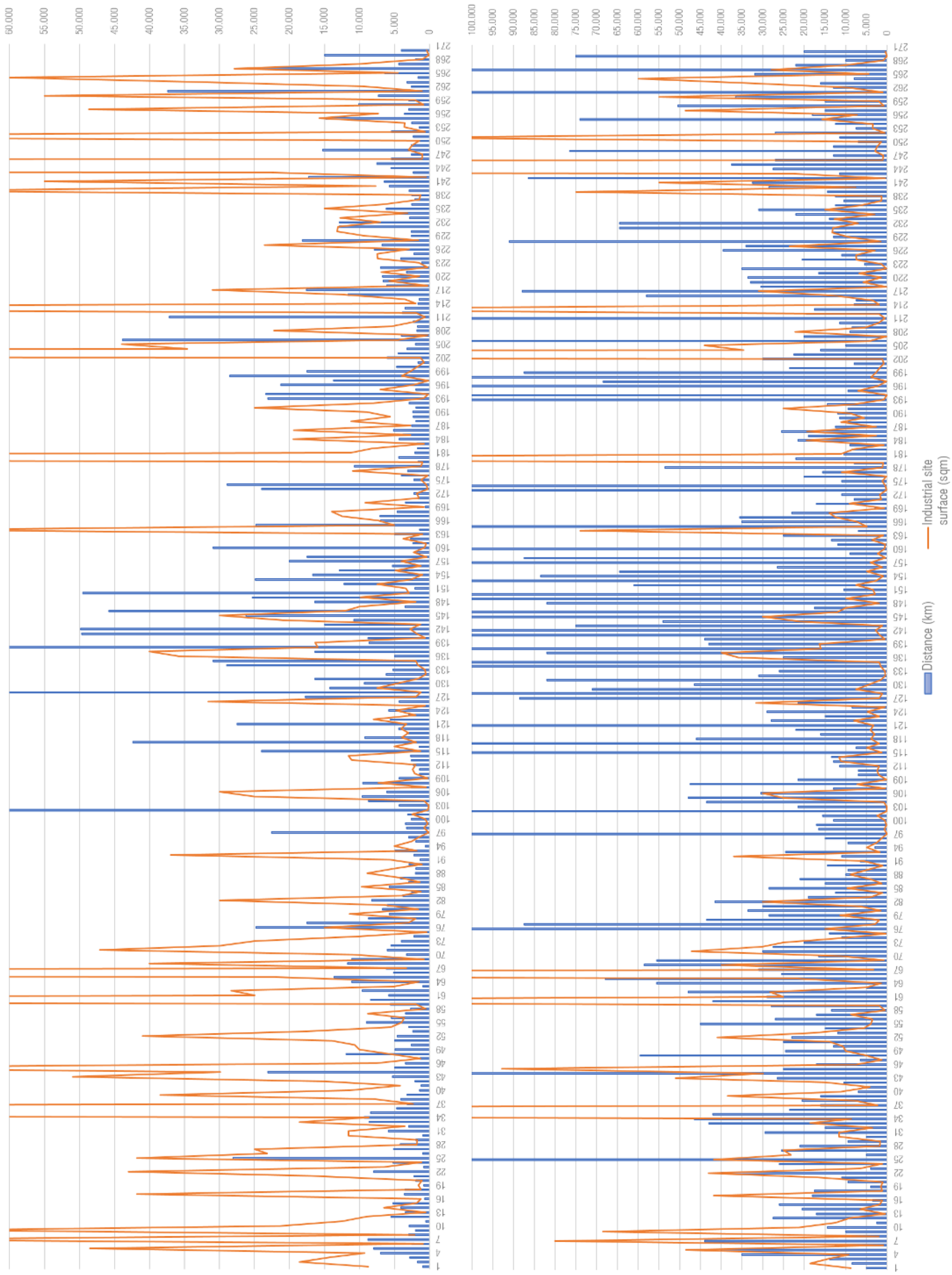


Figure 3.3.3-4b Zoomed diagrams of dimensional and spatial output data comparison.

3.4 Scenarios selection through Multi-Criteria Decision-Making (MCDM) approaches in complex adaptive reuse projects

The development of feasible adaptive reuse strategies in complex design industrial marginal contexts requires the application of effective Multi-Criteria Decision-Making Analyses (MCDMA). MCDMA are widely applied to provide a comparative assessment of different and heterogeneous scenarios, ranking the most suitable solution on the basis of design criteria evaluations.

This section specifies two widespread MCDM models (Multi-Attribute Value Theory; MAVT) (Keeney & Raiffa, 1976; Ferretti et al., 2014) (Optimised Analytic Hierarchy Process; O-AHP) (Sangiorgio, 2018) that allow to extrapolate numerical weights for each parameter, generating tabulated values useful to measure projects feasibility and potential.

Before starting the formulation and calculation of criteria weights and the evaluation of design solutions, the decision problem structuring is the first step to identify the actors of the decision-making process, the scopes to be considered in the multicriteria choice selection models and the morphological, compositional and functional transformation alternatives of the disused industrial site case study.

More precisely, the following three analyses have been performed:

a) The Stakeholders Analysis defines the main actors involved in the adaptive reuse process. In addition, it provides to measure people interest in the conversion intervention, describing objectives and resources that they can bring into play and possible conflicts that may arise. An active participation of stakeholders in the preliminary design stage and face-to-face interactions with members allow to perform a preliminary screening of attributes and design alternatives. This step breaks down the problem complexity integrating different relevant decision makers options;
b) On the basis of expert's surveys data, the criteria analysis summarises the most important drivers of the specific transformation process. Multiple as-

pects are accurately reviewed and investigated in order to obtain a set of measurable parameters for the calculation of scenarios potential. All the attributes are organised according to the value tree structure. At the same time, each attribute is identified with an ID code to facilitate multicriteria analysis procedures. A top down approach and experts interviews are implemented to perform a thorough judgement of criteria raw values for each selected alternative. These information are stored in the raw values table of alternatives;

c) An important step of decision-making models consists in the identification of architectural, morphological and functional alternatives strictly linked with the objectives and purposes arisen from stakeholder's analysis. An accurate and detailed description of reuse and conversion scenarios of derelict warehouses and a careful study of the characteristics and shortcomings of the existing buildings offer the opportunity to hypothesize economically, socially and architecturally effective and achievable solutions.

It is worth noting that multi-attribute evaluation and comparison Decision Support Systems (DSSs) are fundamental tools to quantify planning design hypothesis effectiveness, performing sequential stages to estimate the weights of the independent parameters and the feasibility scores of alternatives. The next step involves the elicitation of qualitative and quantitative function to fix ranges for each design criteria catalogued in the decision-making scenarios ranking.

3.4.1 Elicitation of Value Functions

The development of decision-making support systems must express the value ranges of qualitative and quantitative selected criteria in order to measure the impact of each option under consideration in the design steps of building adaptation. The modelling of such rating parameters can be perceived through the elicitation of value functions (Montibeller & Franco, 2007). These mathematical representations of human judgements provide to estimate reliable values on the basis of an exhaustive stakeholders interviewing process in which the relevant criteria are classified, organised and graphically displayed (Figure 3.4.1-1). In particular, the value function converts the data of the design solutions, summarised in the raw value table of alternatives, into ranges that represent the different degree influences of decision objectives on building conversion interventions. The diagrams architecture varies according to the raw values of alternatives extrapolated by the stakeholder's analysis and by topics and objectives that criteria have to perform. A value score equal to 1 corresponds to the best available performance, while lower ranges decrease objectives achievements (Beinat, 1997). In addition, these diagrams are elicitated by decision makers independently from the compositional and functional design alternatives and composed on the x axis by raw values and on the y axis by numerical ranges. Once the value functions have been designed, it is possible to evaluate and rank the adaptive reuse scenarios of conversion.

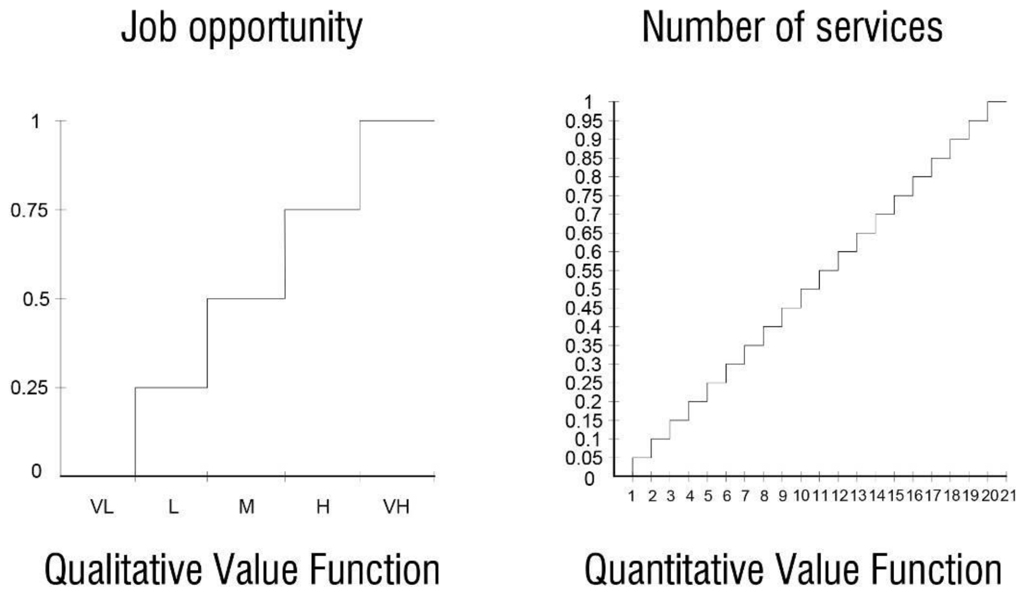


Figure 3.4.1-1 Examples of qualitative and quantitative value functions (Former Radaelli Sud Factory).

3.4.2 The Multi-Attribute Value Theory (MAVT) and the SWING Weight Method

The ranking of alternatives phase represents the main step of multicriteria Decision Support Systems (DSSs). The prioritisation of the different stakeholders' objectives may be performed by the use of different MCDMA. In particular, in this paragraph the MAVT methodology is outlined (Fishburn, 1967; Raiffa, 1969; Keeney & Raiffa, 1976; Ferretti et al., 2014). MAVT analysis can solve adaptive reuse interventions problems, taking into account a finite number of design solutions classified on the basis of pairwise comparisons of n independent criteria. This application allows to weight the selected criteria and the potential of each option through the implementation of three performance matrices. These evaluation tools provide a sequential and alternate paired estimation between two of the three main features (Criteria (A); Adaptive Reuse alternatives (B) and Stakeholders preferences coalitions (C)), using performance matrices and respectively: i) criteria (A) with adaptive reuse alternatives (B) (I performance matrix); ii) stakeholders preferences coalitions (C) with criteria (A) (II performance matrix) and iii) stakeholders preferences coalitions (C) with adaptive reuse alternatives (B) (III performance matrix) (Figure 3.4.2-1).

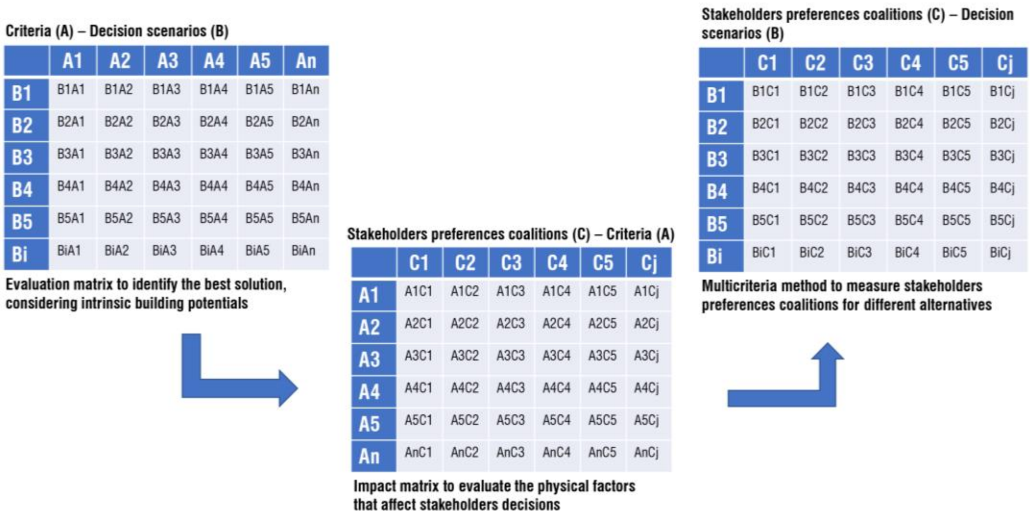


Figure 3.4.2-1 Sequential application of the three performance matrices.

The first performance matrix, based on the information contained in the raw values table of alternatives and in the value functions, standardizes the ranges of the quantitative and qualitative criteria selected for the evaluation of design solutions. For example, if criterion A1, considering solution B1, is evaluated as "HIGH" in the raw values table of alternatives the correspondent value function numeric range parameter A1 will compose the B1A1 label of the matrix (Figure 3.4.2-2).

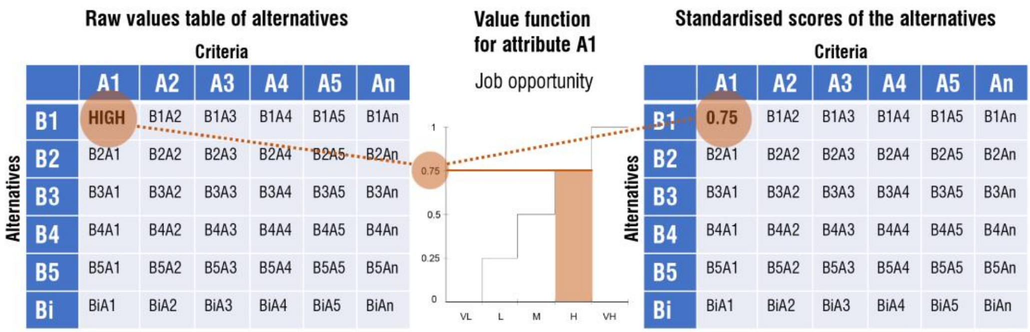


Figure 3.4.2-2 Standardisation of scenarios scores (I performance matrix).

Once stored all the data concerning the alternatives raw values, the next step consists in the definition of attributes weights that characterise the ranking process. In particular, the MAVT methodology accounts one of the most common and intuitive assessment tools for criteria weights calculation, the SWING Weight Method (Montibeller & Franco, 2007; Schuwirth et al., 2012). This technique incorporates parameters values in the survey and considers a reference state in which all attributes are at their worst condition, elicited from the value function. Interviews question decision makers, specialised in different construction fields, to weight different scenarios, assuming that only one criterion could be improved to best level condition ensured by the value functions. For each different option in the questionnaire, stakeholders give a value to this swing in the range 0-100 (Figure 3.4.2-3). All the scores provided by experts are normalised, obtaining a set of weights for all the accounted criteria. These outputs composed the second performance matrix (Figure 3.4.2-4).

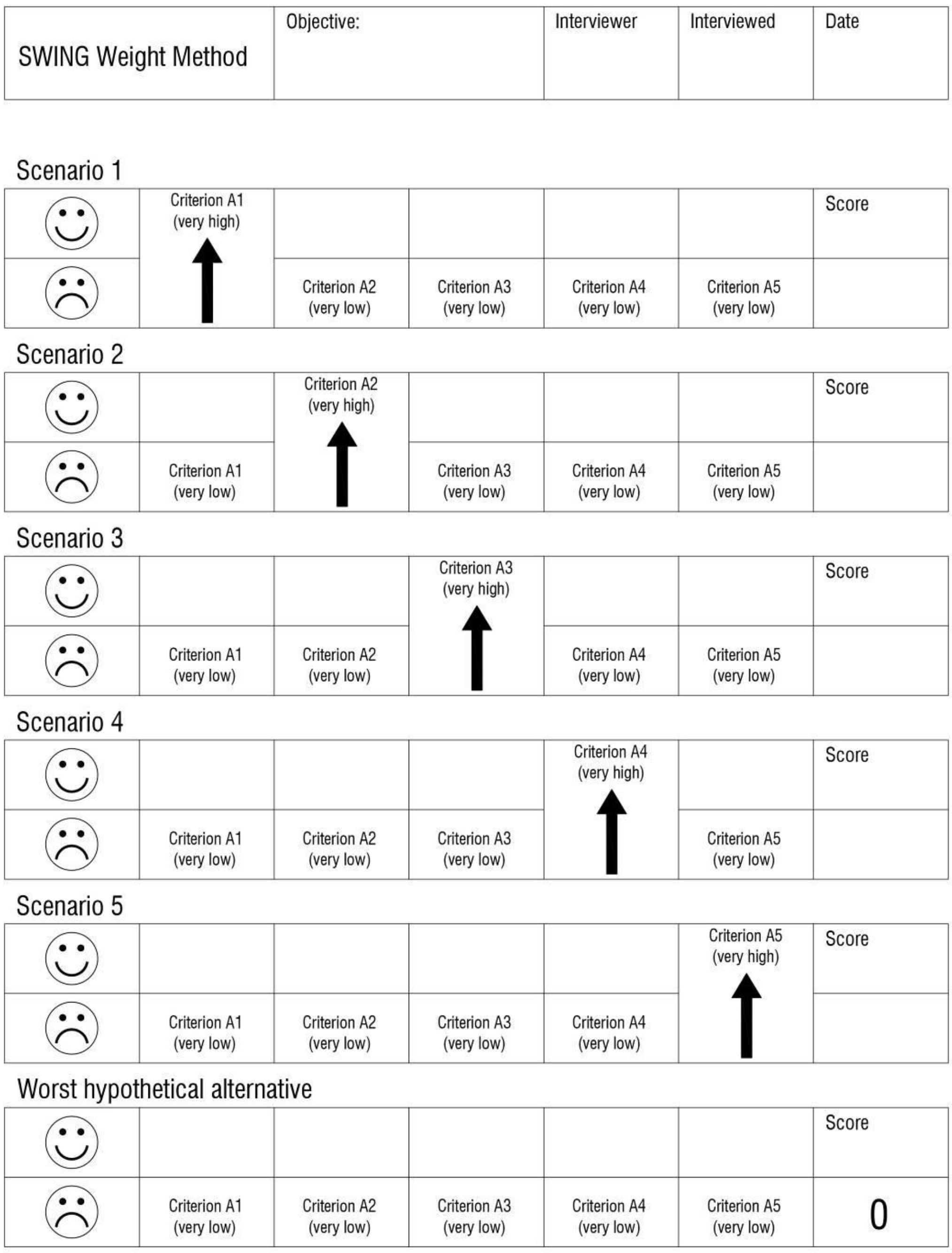


Figure 3.4.2-3 SWING Weight Method questionnaire layout for experts score elicitation.

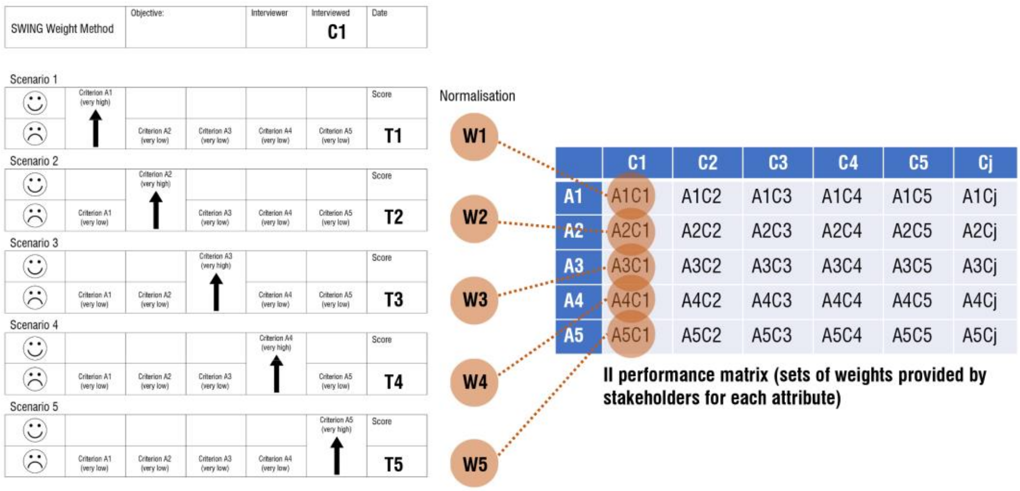


Figure 3.4.2-4 Normalisation of SWING Method experts scores and filling of II performance matrix.

The last performance matrix of MAVT aggregates the data extrapolated by the two previous stages through the use of additive model of evaluation (Belton & Stewart, 2002) represented by the equation (Eq. 3.4.2-1):

$$V(B1)=\sum Wn * Vn(Bn) \qquad (3.4.2\text{-}1)$$

where:
V(B1) is the final rank of the alternative B1;
Wn is the weight assigned to the attribute n by the decision maker C1;
Vn(Bn) is the value function standardized score of scenarios B1 considering the attribute n (Figure 3.4.2-5).

At the end of the alternatives potential ratings formulation, the best adaptive reuse scenario according to the sets of weights and ranking diagrams has been selected for its implementation in the DCS for the structuring and formulation of the preliminary conversion strategy. A synthesis of the MAVT + SWING Weight methodology phases is summarised in Figure 3.4.2-6 (Figure 3.4.2-6).

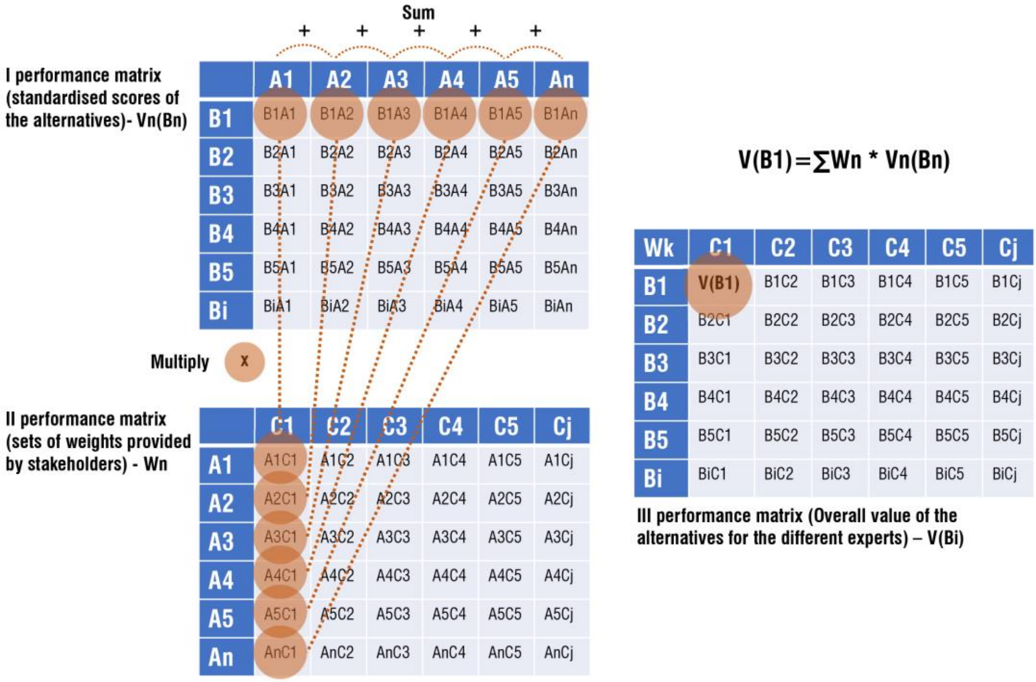


Figure 3.4.2-5 Calculation of the overall values of the alternatives for the different stakeholders.

3.4.3 The Optimised Analytic Hierarchy Process (O-AHP)

In this paragraph, the second methodological multicriteria decision-making approach (O-AHP) used to classify and analyse the parameter involved in the adaptive reuse transformation processes of abandoned industrial warehouses and to calibrate the index I_{AR} is presented. The O-AHP (Sangiorgio, 2018; Sangiorgio et al., 2018a; 2018b) is an improved and well-structured DSS based on the classical Analytic Hierarchy Process (AHP) three sequential steps specified in the following section: i) hierarchical problem structuring, ii) weight evaluation, iii) summary of priority. In particular, the O-AHP is implemented when the user is not able to carry out the required consistency of the output data in the first attempt through the application of the AHP. In addition, this original decision-making tool supports choices in complex design contexts when lots of attributes and alternatives must be evaluated and ranked.

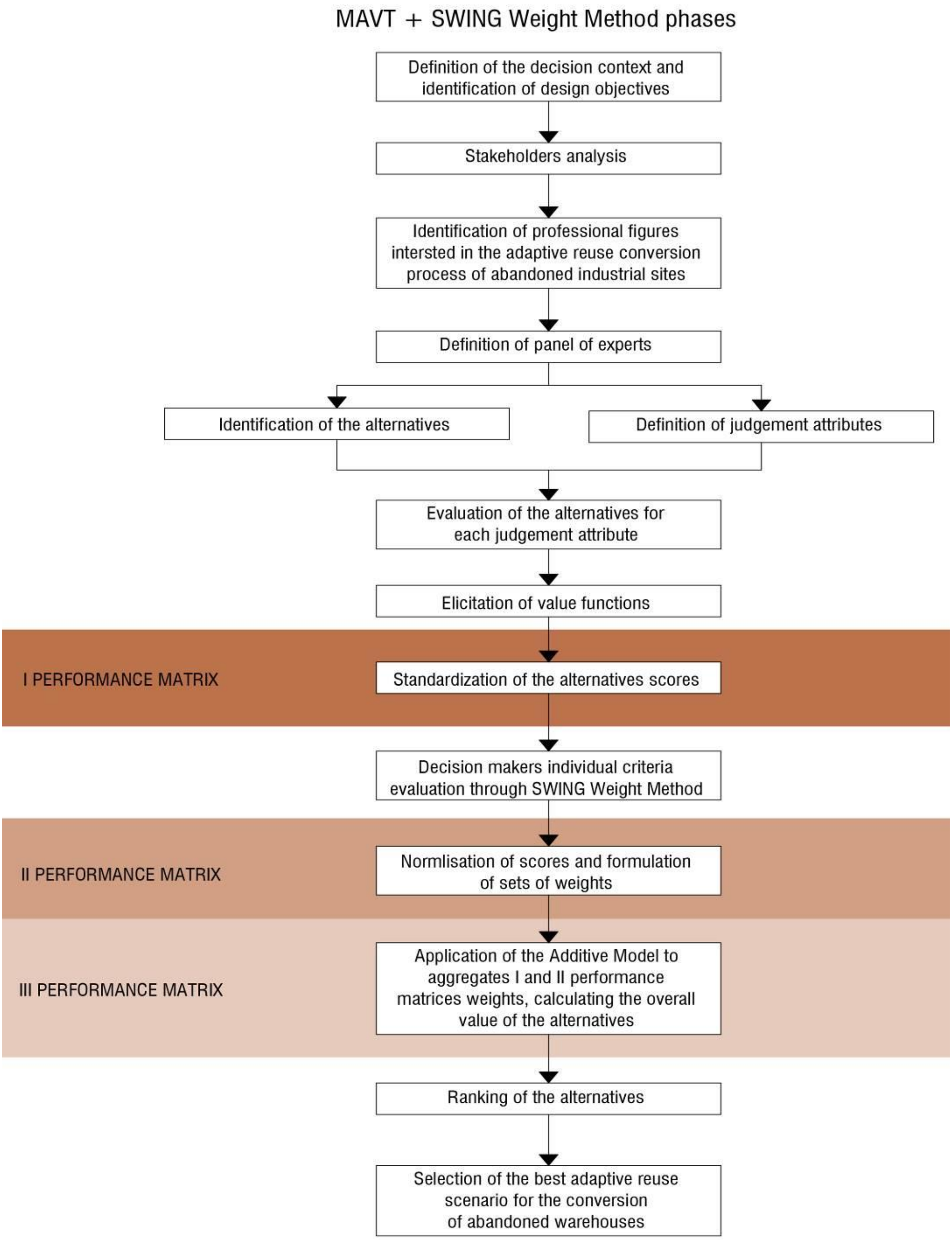


Figure 3.4.2-6 MAVT + SWING Weight Method scheme of the decision support system.

In these situations, the weight evaluation step is repeated by redefining the judgement assignments, generating the matrix of judgement with the help of a mathematical programming formulation. The main procedures that characterise the O-AHP are illustrated in Figure 3.4.3-1 (Figure 3.4.3-1). Starting from the definition of the decision context, the first phase (classical AHP) consists in the structuring of the problem according to a hierarchical scheme. This part of the methodology provides a detailed, intuitive and systematic decomposition of the problem into its basic features. The weight evaluation phase calculates the weights necessary for generating the final rankings. It can be considered the core of the selected approach. In this step, the decision maker individually scans each component of the decision problem. Taking into account n ordered criteria of comparison (i.e., criteria or sub-criteria), a matrix of judgments A is defined (Figure 3.4.3-2) (Saaty, 2008), where each upper diagonal element >0 is generated by comparing the i-th element with the j-th one through the fundamental scale of absolute numbers (Saaty, 2008). The evaluation of the importance of one element over another is developed by using this semantic scale. The latter is composed by verbal scales and numerical values (e.g. Equal importance $a_{ij}=1$, Moderate importance $a_{ij}=3$, Strong importance $a_{ij}=5$, Very strong importance $a_{ij}=7$, Extreme importance $a_{ij}=9$). The methodology also ensures the insertion of intermediate and decimal values (e.g. 1.5, 2, 4, 6, 8). According to Saaty (Saaty, 2008), AHP derives ratio scale priority vectors from matrix A by exploiting the principal eigenvalue method. The weights are extrapolated by solving the following eigenvector problem (Eq. 3.4.3-1):

$$A\,w = \lambda max\,w \qquad (3.4.3\text{-}1)$$

where w is the eigenvector and λmax is the principal eigenvalue. In addition, Saaty (Saaty, 1987), in his researches, determines the Consistency Index (CI) (Eq. 3.4.3-2) to check the coherence of the assigned judgement. The CI is defined as follows:

$$CI = \frac{\lambda_{max} - n}{n-1} \qquad (3.4.3\text{-}2)$$

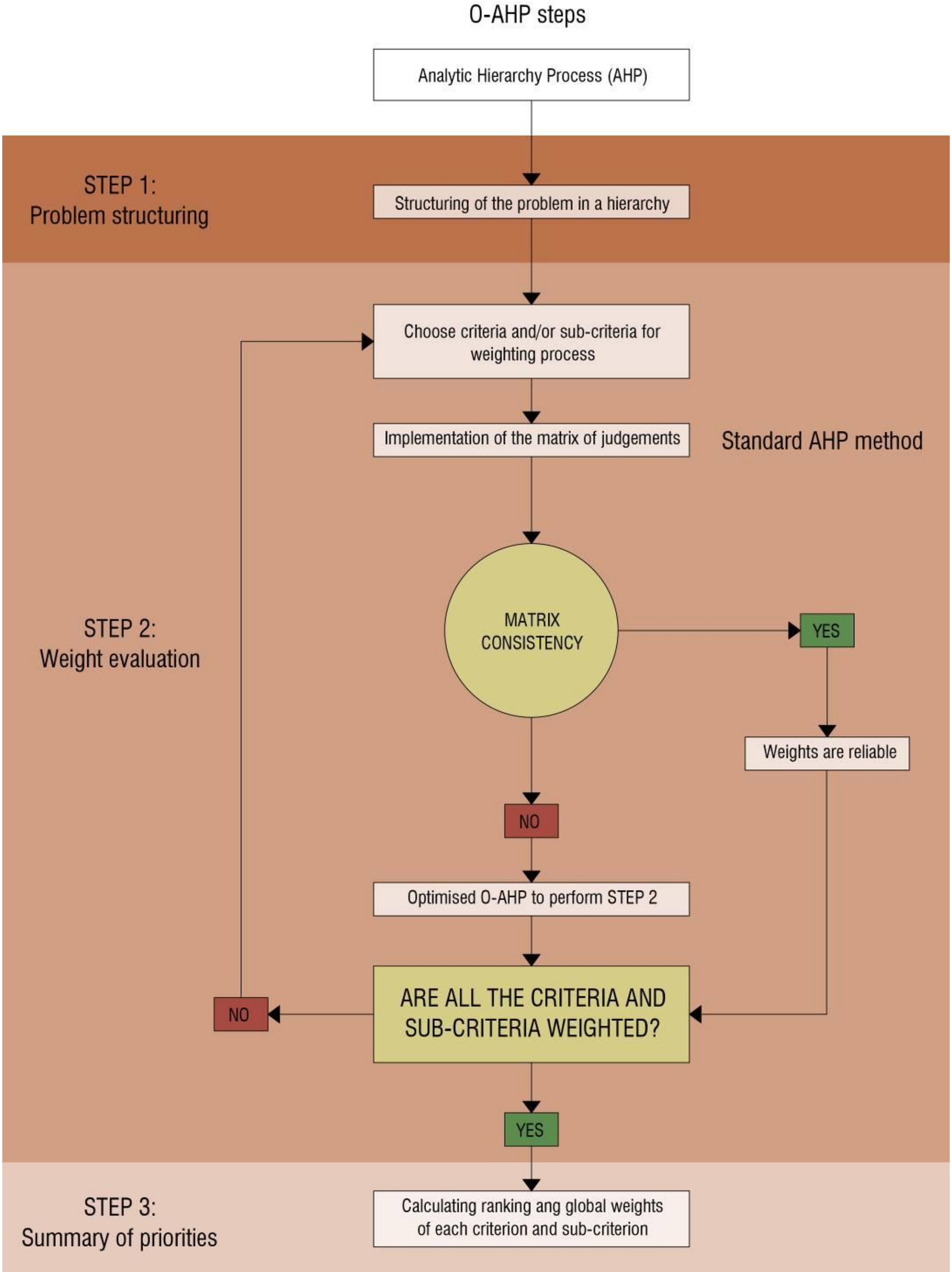


Figure 3.4.3-1 Steps of Optimized-AHP.

A	1	2	...	n
1	1	$a_{1,2}$	...	$a_{1,n}$
2	$1/a_{1,2}$	1	...	$a_{2,n}$
...	...	...	1	...
n	$1/a_{1,n}$	$1/a_{2,n}$	...	1

Figure 3.4.3-2 Generic matrix of judgments A.

The control of pairwise comparisons consistency, of result reliability and of output data robustness and coherence is performed through the evaluation of the Consistency Ratio (CR). CR (Eq. 3.4.3-3) is obtained by the ratio between CI and its expected value denoted as Random Index (RI). RI is estimated considering a large number of positive reciprocal matrices of order n whose entries information are randomly chosen in the set of values n $=\{1,2,..., 10\}$. In particular, it holds:

$$CR = CI/RI(\mathrm{n}) \qquad (3.4.3\text{-}3)$$

In this research methodology, Noble and Sanchez RI values (Noble & Sanchez, 1993) (Table 3.4.3-1) are taken into account.
On the basis of several empirical studies, Saaty (Saaty, 1987) affirms that a Consistency Ratio score less than 0.10 ($CR < 0.10$) is acceptable (Saaty, 2003).

Generally, the last step of DSS can be faced up when the consistency is obtained. However, if the selected scenario presents a multiplicity of parameters to rank or the complexity of the transformation intervention is high, it is difficult to achieve the consistency requirement. To this reason, the O-AHP (Sangiorgio, 2018; Sangiorgio et al., 2018a; 2018b) methodology is accounted in the present work with the aim to assess the correct consistency scores and avoid the limitation of a trial and error approach.

n	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*	*13*	*14*	*15*
R.I.	0	0	0.49	0.82	1.03	1.16	1.25	1.31	1.36	1.39	1.42	1.44	1.46	1.48	1.49

Table 3.4.3-1 Random consistency index of Noble and Sanchez (Noble & Sanchez, 1993).

More specifically, if the user is not able to reach the consistency using the classical AHP, the O-AHP tool supports the decision maker to attain the upper diagonal elements $a_{ij}>0$ by a Mathematical Programming (MP) problem formulation. The main peculiarity of this approach resides in the assignment of the Judgement Ranges instead of the ratings of the standard AHP to define the elements a_{ij}. In particular, the decision maker assigns the Judgement Ranges by using the O-AHP tables that list upper and lower bounds (Tables 3.4.3-2; 3). This procedure allows to set the lower and upper bounds of the matrix elements a_{ij} in the formulation problem.

Moreover, the sets of pairs of sub-attributes that are subjected to the judgement range inequalities are determined as follows:

$C^L = \{(i,j) \mid a_{ij} > K_{ij}^L \ with\ i < j\}$ set of pairs of sub-criteria involved in lower bound inequalities,

$C^U = \{(i,j) \mid a_{ij} \leq K_{ij}^U \ with\ i < j\}$ set of pairs of sub-criteria involved in upper bound inequalities.

Lower bound constraint	Verbal constraint
$a_{ij} \geq 1$	Equal or more importance of i over j
$a_{ij} \geq 2$	More importance, even if slightly, of i over j
$a_{ij} \geq 3$	At least moderate importance of i over j
$a_{ij} \geq 5$	At least strong importance of i over j
$a_{ij} \geq 7$	At least very strong importance of i over j
$a_{ij} \geq 9$	Maximum importance of i over j
1.5 - 4 - 6 - 8	Intermediate value
$a_{ij} \leq (1/9, 1/8, \ldots, 1)$	The reciprocal number with the less-equal-than sign express an opposite judgement (Becomes upper bond)

Table 3.4.3-2 O-AHP semantic ranges of the lower bounds.

Upper bound constraint	Verbal constraint
$a_{ij} \leq 2$	The importance of i over j does not exceed the "minimum importance"
$a_{ij} \leq 3$	The importance of i over j does not exceed the "moderate importance"
$a_{ij} \leq 5$	The importance of i over j does not exceed the "strong importance"
$a_{ij} \leq 7$	The importance of i over j does not exceed the "very strong importance"
$a_{ij} < 9$	The importance of i over j does is not the Max importance
1.5 - 4 - 6 - 8	Intermediate value
$a_{ij} \geq (1/9, 1/8, \ldots, 1/2)$	The reciprocal number expresses an opposite judgement (Becomes lower bond)

Table 3.4.3-3 O-AHP semantic ranges of the upper bounds.

Where K_{ij}^{L} and K_{ij}^{U} are the lower and upper bound constraints values assigned by the decision maker.
Hence, the entries and input data of matrix A are itemised by the following set Γ(A) (Eq. 3.4.3-4a; b; c; d; e) of mathematical constraints:

Γ(A):

$a_{ij}=1$ for $i,j=1,\dots,n$ with i=j (3.4.3-4a)

$1/9 < a_{ij} < 9$ for $i,j=1,\dots,n$ with i<j (3.4.3-4b)

$a_{ij} \le K_{ij}^{U}$ for $(i,j) \in C^{U}$ (3.4.3-4c)

$a_{ij} > K_{ij}^{L}$ for $(i,j) \in C^{L}$ (3.4.3-4d)

$a_{ij} = 1/a_{ji}$ for $i,j=1,\dots,n$ with i>j (3.4.3-4e)

The equations 3.4.3-4a; b; e (Eq. 3.4.3-4a; b; e) determine constraints derived from the definition of matrix A; equations 3.4.3-4c; d (Eq. 3.4.3-4c; d) explain constraints defined by the decision maker. The computation of the judgment matrix to exhibit low consistency index is performed by the MP problem set as follows (Eq. 3.4.3-5a; b):

min CI(A) (3.4.3-5a)

subject to Γ(A) (3.4.3-5b)

where the weights w are formulated by solving the eigenvector problem of equation 3.4.3-1 (Eq. 3.4.3-1) and CI is evaluated according to the equation 3.4.3-2 (Eq. 3.4.3-2).
The Optimised Judgement Matrix A^{opt} of the generic element a_{ij}^{opt} is computed by solving the MP problem (3.4.3-5a; 5b), ensuring the estimation of the optimised weights w^{opt} of each design attribute.

The third step (summary of priority) outlines the global rankings and the global weights. To perceive this purpose, the weights of each criterion are combined with the weights of the sub-criteria (Saaty, 1990).

In such a way, the multiplication between each criterion weight (v_i) and sub-criterion weight $(w_{i,j})$, explained by the equation 3.4.3-6 (Eq. 3.4.3-6), allows to obtain the global weights $(w'_{i,j})$.

$$w'_{i,j} = v_i * w_{i,j} \tag{3.4.3-6}$$

The described DSS contributes to develop a novel index to predict the potential effectiveness and feasibility of an adaptive reuse conversion project (named I_{AR}), defining criteria, sub-criteria and the related intensity range.
In particular, the data related to a renovation project, analysed by using the previously mentioned index, are represented by the intensity range $p_{i,j,k}$ (normalized to 1), with respect to the i-th criterion and the j-th sub-criterion.
Once all the intensity ranges $p_{i,j,k}$ of the considered reuse plan are extrapolated from the value functions, the I_{AR} formula can be applied to have a numerical output score to quantify the effectiveness of the project, making comparisons with diverse design and functional assumptions. The index I_{AR} can be easily obtained by practitioners using a simple and consistent equation highlighted in the O-AHP procedure of Sangiorgio et al. (Sangiorgio, 2018; Sangiorgio et al., 2018a; 2018b) (Eq. 3.4.3-7):

$$\boldsymbol{I_{AR}} = w'_{1,1} * p_{1,1,k} + w'_{1,2} * p_{1,2,k} + w'_{1,3} * p_{1,3,k} + \cdots + w'_{4,11} * p_{4,11,k} \tag{3.4.3-7}$$

where v_i and w_{ij} are the weights associated to the criteria i and to the sub-criterion j respectively and $p_{i,j,k}$ are the weight related to the specific intensity range of the analysed adaptive reuse conversion solution.

3.5 Implementation of the Design Criteria System (DCS) to manage adaptive reuse criteria

The fourth section of the methodology highlights factors that most affect adaptive reuse processes of derelict warehouses, cataloguing and classifying all the components in the DCS graph.

The DCS represents a multicriteria tool that allows to manage huge amounts of data analysed in the state-of-the-art, having a general perspective of the topics examined by the authors, regarding the design criteria in the field of adaptive reuse. Table 3.5-1 (Table 3.5-1) contains the articles analysed in the literature review for the characterization of the model components, dividing them into the seven design areas identified by Langston et al. and Conejos et al. (Langston et al., 2007; Langston, 2008; Langston, 2011; Conejos & Langston, 2010; Conejos et al., 2011; 2013; Conejos, 2013a; 2013b). The goal of this decision support diagram consists in the identification of feasible and sustainable solutions for the conversion of empty and dismissed industrial sites (Vizzarri & Fatiguso, 2019; Vizzarri, 2020; Vizzarri et al., 2020a; b; c). In addition, this radio-centric model outlines risks that can compromise the success of the adaptive reuse intervention. Moreover, this evaluation system is designed to facilitate stakeholder's decisions, simulating possible intervention strategies based on conceivable design scenarios.

Main design criteria	*Relevant research study*
Physical Design Criteria (building level of decay; refurbishment activities; construction interventions)	Ousbourne, 1985; Grammenos & Russell, 1997; Kincaid, 2000; Russell & Moffat, 2001; Davison et al., 2006; Siddiqi, 2006; Douglas, 2006; Browne, 2006; Vakili-Ardebili, 2007; Prowler, 2008; Yudelson, 2010; Horvath, 2010; Conejos et al., 2011; Plevoets & Van Cleempoel, 2011; Conejos et al., 2012; Conejos et al., 2013; Kirovovà & Sigmundovà, 2014; Savvides, 2015; Conejos et al., 2015; Guadagno et al., 2015; Orhon, 2016; Conejos et al., 2016; Boarin et al., 2016; Fisher-

	Gewirtzman, 2016; Misirlisoy & Gunce, 2016; Wilkinson & Remoy, 2017; Li et al., 2018; Tam & Yao, 2018; Othman & Elsaay, 2018; Vardopoulos, 2019; Morandotti et al., 2019; Umar et al., 2019
Economic Design Criteria (Costs; market influence)	Campbell, 1996; Kincaid, 2000; Heath, 2001; Davison et al., 2006; Douglas, 2006; Browne, 2006; Langston et al., 2008; Tobias & Vavaroutsos, 2009; Conejos et al., 2011; Wang, 2011; Conejos et al., 2012; Kimball & Romano, 2012; Conejos et al., 2013; Kirovovà & Sigmundovà, 2014; Loures, 2015; Misirlisoy & Gunce, 2016; Prat Forga & Canoves Valiente, 2017; Di Feliciantonio et al., 2018; Othman & Elsaay, 2018; Umar et al., 2019; Vardopoulos, 2019
Functional Design Criteria (Services; space flexibility)	Grammenos & Russell, 1997; Kincaid, 2000; Russell & Moffat, 2001; Heath, 2001; Arge, 2005; Graham, 2005; Douglas, 2006; Davison et al., 2006; Vakili-Ardebili, 2007; Prowler, 2008; Langston et al., 2008; Whimster, 2008; Rabun & Kelso, 2009; Horvath, 2010; Nakib, 2010; Zeiler et al., 2010; Conejos et al., 2011; Conejos et al., 2012; Temelova & Dvorakova, 2012; Conejos et al., 2013; Kirovovà & Sigmundovà, 2014; Yung et al., 2016; Misirlisoy & Gunce, 2016; Umar et al., 2019
Technological Design Criteria (Passive technologies; materials; envelope and structural solutions)	Ousbourne, 1985; Grammenos & Russell, 1997; Park, 1998; Russell & Moffat, 2001; Douglas, 2006; Davison et al., 2006; Shaw et al., 2007; Prowler, 2008; Langston et al., 2008; Dittmark, 2008; Tobias & Vavaroutsos, 2009; Conejos et al., 2011; Conejos et al., 2012; Conejos et al., 2013; Kirovovà & Sigmundovà, 2014; Thomas Ng, 2014; Conejos et al., 2016; Conejos et al., 2016; Wilkinson & Remoy, 2017; Vardopoulos, 2019; Umar et al., 2019

Social Design Criteria (Stakeholders; sense of place; social analysis)	Campbell, 1996; Grammenos & Russell, 1997; Russell & Moffat, 2001; DEH, 2004; Fournier & Zimnicki, 2004; Zushi, 2005; Douglas, 2006; Davison et al., 2006; Browne, 2006; Fealy, 2006; Shaw et al., 2007; Prowler, 2008; Bond & Charlemagne, 2009; Tobias & Vavaroutsos, 2009; Fadda et al., 2010; Plevoets & Van Cleempoel, 2011; Conejos et al., 2011; Andersson, 2011; Conejos et al., 2012; Temelova & Dvorakova, 2012; Conejos et al., 2013; Haidar & Talib, 2013; Agaliotou, 2015; Yung et al., 2016; Mohamed & Alauddin, 2016; Misirlisoy & Gunce, 2016; Prat Forga & Canoves Valiente, 2017; Gholitabar et al., 2018; Othman & Elsaay, 2018; Umar et al., 2019; Vardopoulos, 2019; Aigwi et al., 2020
Legal Design Criteria (Safety & security; quality standards)	Ousbourne, 1985; Park, 1998; Douglas, 2006; Davison et al., 2006; Prowler, 2008; Gilder, 2010; Conejos et al., 2011; Conejos et al., 2012; Conejos et al., 2013; Savvides, 2015; Ijla & Brostrom, 2015; Wilkinson & Remoy, 2017; Di Feliciantonio et al., 2018; Umar et al., 2019; Vardopoulos, 2019
Political Design Criteria (Zoning; urban master plan; ecological footprint)	Campbell, 1996; Kincaid, 2000; Heath, 2001; Fournier & Zimnicki, 2004; Douglas, 2006; Davison et al., 2006; Browne, 2006; Langston & Shen, 2007; Langston et al., 2008; Gilder, 2010; Conejos et al., 2011; Andersson, 2011; Conejos et al., 2012; Conejos et al., 2013; Li et al., 2018; Di Feliciantonio et al., 2018; Umar et al., 2019

Table 3.5-1 Articles analysed for the implementation of DCS diagram.

The steps for the design of the DCS structure and the implementation of adaptive re-use solutions for abandoned sheds can be resumed as follows:

A) Identification and description of the main topic that influence stakeholders decision-making choices and industrial sites conversions;
B) Definition of DCS structure, identifying the layers, diagram morphology, sections and sub-sections;
C) Implementation of the DCS with the insertion of attributes, sub-attributes and activities and determination of features ID codes;
D) Parameters and risks weight evaluation through interviews and focus groups;
E) Management of DCS components in the building recovery table;
F) Detection of design criteria, attributes and sub-attributes relationships and interactions;
G) Formulation of adaptive reuse feasible strategies in the building recovery table on the basis of building cataloguing sheet information and evaluation of project feasibility coefficient (f) and risk entity (r);
H) Preliminary costs estimation of the adaptive reuse intervention;
I) DCS validation through ARP and AdaptSTAR Models.

The DCS facilitates the development of adaptive reuse policies, giving the possibility to activate innovative refurbishment interventions of abandoned marginal factories, through automatic and user-friendly tools. Multicriteria decision-making analyses could be an adequate solution to formulate smart adaptive reuse alternatives considering a set of selected criteria and to estimate the feasibility and adaptability of each scenario.

3.5.1 Definition of DCS main choice categories

All the information, derived from the literature review process, are distinguished in thematic categories of factors that affect experts' decisions in complex adaptation, refurbishment and design adaptive reuse interventions on abandoned industrial contexts. The development of the DCS evaluation tool is implemented by considering as valid and reliable the seven adaptive reuse design features outlined by Langston et al. and Conejos et al. (Langston et al., 2007; Langston, 2008; Langston, 2011; Conejos & Langston, 2010; Conejos et al., 2011; 2013; Conejos, 2013a; 2013b. These seven scopes give a complete and exhaustive overview of the issues and activities that most directly affect recovery policies on the disused industrial contexts. Adaptive reuse parameters are classified into seven sections representing physical, economic, functional, technological, social, legal and political design categories (Figure 3.5.1-1). The seven categories identified in the literature cover all fields of building design, promoting an accurate preliminary definition of innovative regeneration models for the transformation of industrial urban assets.

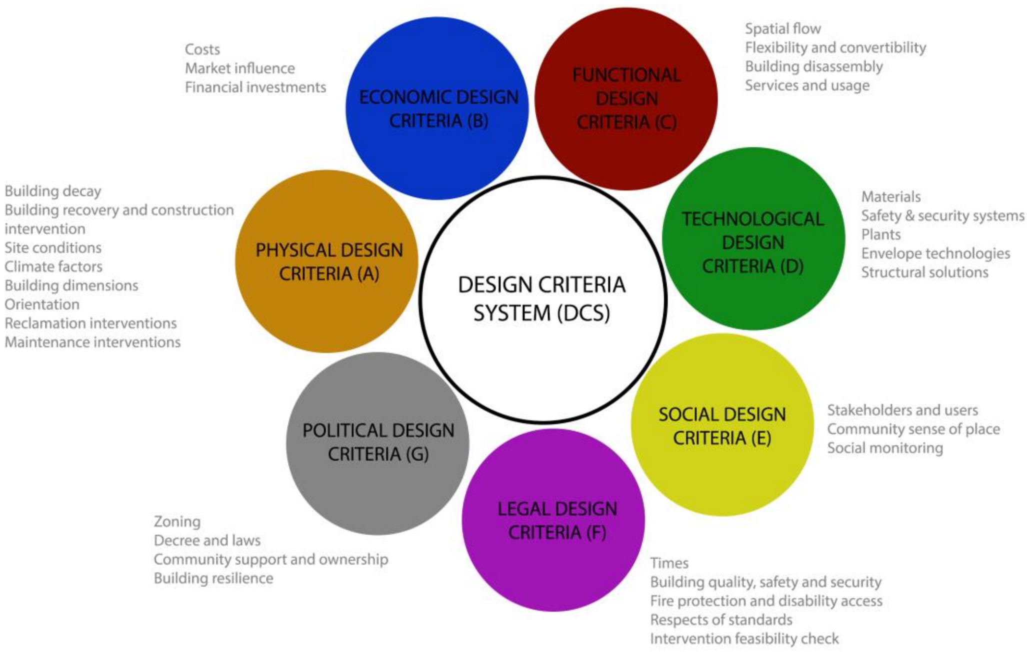


Figure 3.5.1-1 Design Criteria System main categories diagram.

In particular, the components managed in the seven main design categories are summarized as follows:

1) Physical Design Criteria (A): it describes physical and visual parameters that characterise dismissed factories, buildings degree of obsolescence, refurbishment and construction intervention on the existing structures. This first category of the DCS, therefore, lists attributes that evaluates the level of decay of dismissed warehouses and environmental aspects that can amplify the deterioration processes of building components. In particular, considering existing and abandoned envelopes, attributes and sub-attributes that assess the architectural components level of degradation also evaluate the obsolescence of the technological, plant, and spatial solutions inserted in the industrial volumes. In addition, Physical Design Criteria englobes formal and compositional alternatives that modify the building shape, its envelope, the interior and exterior spaces, and the pre-intervention monitoring activities to be carried out for a detailed analysis of the most damaged parts. Such section of the DCS synthesises both refurbishment and modern architectural interventions on the existing. Moreover, adaptive reuse processes not only involve the building structure, but also consider the opportunities that the extension of the lot in which the shed is inserted can offer. The elements contained in this sector of the multicriteria system define the level of urban traffic, the road and plant infrastructure present in the neighbourhood and the degree of environmental context pollution. At the same time, categories related to the protection and management of the external and urban spaces intrinsic in the case study morphology are not excluded from the model. Dimensional and volumetric scopes, building orientation, geographical localization and the architectural and landscape quality of the context are useful attributes to highlight whether the proposed adaptive reuse strategy can be pursued or not. Weather factors and constraints and orographic risks that can promote structural and aesthetic deterioration of the area are also accounted. Reclamation and maintenance

interventions data complete Physical Design Criteria parameters classification in the DCS. These two typologies of intervention summarize the reclamation activities to decontaminate polluted industrial sites and post-recovery and adaptation maintenance actions to increase the building useful life.

2) Economic Design Criteria (B): this second thematic design field that composes the DCS summarises all economic factors regarding the design, management and construction adaptive reuse steps. In particular, the transport, construction, conversion, materials and reclamation costs, the actions to reduce pollution, the maintenance works and the bureaucratic and design burdens are explained in this section. Building level of decay and structural constraints may affect building costs. These two features must be considered at the beginning stages of a reuse project since the cost of reusing and reforming existing structures can overcome the demolition and new construction costs (Kirovovà & Sigmundovà, 2014). Public and private financial investments are fundamental economic attributes to develop the quality of the adaptive reuse project, perceiving sustainability issues. In addition, a sub-section of Economic Design Criteria is dedicated to identifying the major factors that can affect the property demand, supply and life quality that building transformation projects can bring to the peripheral environment. It also considers and evaluates parameters relating to the promotion of job opportunities in the new intervention hypothesis, as well as the possible profits that the introduced functions can ensure.
3) Functional Design Criteria (C): this section outlines functions and services that can be implemented into dismissed industrial surfaces and volumes, as well as measures the level of flexibility and connectivity of the warehouses spaces. In addition, a part of the Functional Design Criteria lists the spatial components and types of paths able to manage people flows inside the building, guaranteeing the users safety in each external and internal area and the possibility to easily reach all the hypothesised functions in tranquillity. Eleven main general functions compose the last sub-section. The same are also de-

tailed with the inclusion of specific services that individual building units can accommodate. Functional Design Criteria ensure a better choice of architectural reuse solutions, simplifying decision-making in the design and planning phases. Stakeholders choices for the refurbishment and valorisation of dismissed industrial areas are closely related to the social sphere and building physical characteristics. For instance, attributes concerning the building level of decay, surfaces, lot extension and urban context characteristics restrict the decision-making apparatus on feasible recovery adaptive reuse scenarios. Accurate studies of social behaviours and detailed analyses of community lacks and hierarchies provide the development of efficient and interconnected functional programs that can satisfy population needs, strengthening local inclusion and relationships.

4) Technological Design Criteria (D): it accounts technological, plants, materials and vertical and horizontal closures solutions that can be applied on industrial building components during recovery works. The materials sub-attributes are divided according to their main intrinsic components. In addition, the scheme also includes sustainable contemporary and under experimentation materials newly applied in the building field (e.g. carbon fiber, cor-ten, corian, nano materials, phase change materials, energy changing materials). This category, therefore, lists smart, control and protection remote devices, like domotic smart devices and sensors, that amplify building security, monitor technologies performances, detect system problems and increase indoor safety and comfort. Technological Design Criteria describe the possible interventions on the building envelope (e.g. shadings, façade technologies, thermal and acoustic insulation and natural ventilation and lighting), changing its performance in terms of energy saving, and its aesthetic appearance and shape. Considering high-performance and sustainable materials in building adaptation projects, these components improve the thermo-igrometric and environmental conditions of the reused shed, as well as provide architectural options that are visually pleasing. Home automation solutions, passive design plans and moni-

toring systems make the converted marginal space no longer obsolete, expanding its useful life cycle and automating the management of the intelligent systems inserted in the building body.

5) Social Design Criteria (E): the fourth DCS section lists the actors who participate in the design, management, control and implementation of adaptive reuse design steps. Sub-attributes outline the professional figures that most affect the decision phases for urban regeneration interventions. These experts are distinguished according to the refurbishment intervention processes. In particular, Social Design Criteria category includes stakeholders that participates to the management and organization of building reuse activities, the project development, the bureaucratic field, the cultural and historical preservation sphere, since considering professionals involved in the building realization of the adaptive reuse intervention. Users, cultural associations and other figures that can use the transformed space are also considered in the multicriteria scheme. Community analyses and active monitoring of society alterations allow to specify and frame the contemporary main needs and shortcomings in the existing city fabric, providing, through warehouses transformation policies, to the creation of effective and innovative solutions, aiming at social inclusion and districts development. Citizens represent a fundamental source in the decision-making procedures, because they are the first users of the reused and converted goods. At the same time, social features are strictly linked to the inhabitants' sense of belonging regarding the iconicity and historical importance of places during time. The sense of place, recognition of the context importance, site attractiveness, aesthetic identity and the future usability of spaces by the local community are fundamental parameters in order to establish feasible and smart factories adaptation models.

6) Legal Design Criteria (F): it provides to the definition of design components that can affect project times, building quality and safety parameters, as well as lists the design, construction and urban standards that stakeholders must respect during the shed adaptation processes. More specifically, building re-

furbishment steps are differentiated on the basis of main design activities involved in the adaptive reuse interventions to easily discover and evaluate the major sub-attributes that can affect times. This analysis allows stakeholders both to understand, in the preliminary monitoring phase, the actions that require a greater use of human resources and processing times, and to probe any alternative reuse scenarios. The decreasing of building adaptation time can be perceived if the transformation hypothesis combines building functions, performances and architectural quality issues, satisfying modern social needs, solving urban and morphological constraints and limiting bureaucratic procedures for approving the preliminary, definitive and executive project. The building can be compared to a dynamic, complex and time-changing organism that modifies its characteristics through human interventions, meeting quality, safety and security aspects. Legal Design Criteria assess the impact that these parameters have on users and on factories transformations. Moreover, the refurbishment actions and conversion options of abandoned warehouses must adhere to urban standards. These micro-scopes fix design limits, defining the minimum distances between close facades, buildings surfaces, volumes and heights, and environmental and urban parameters to be foreseen in city contexts.

7) Political Design Criteria (G): the last main macro-scope encompasses the legislative and bureaucratic regulations and legislations that govern urban city strategic development and building transformation interventions. This DCS section summarises town planning policies concerning district zoning classification, site geographical localization, municipal, national and international laws, regulatory plans, energy certifications and building resilience in the contemporary dynamic city structure. More specifically, the first sub-section englobes site, logistical and morphological features that classify urban tissues uses destination and frame the relationships between building fabric and master plan composition. Zoning analysis facilitates the identification of future functions to be attributed to the disused volumes. However, recovery, preser-

vation and construction decrees and laws limit the field of choice for adaptive reuse interventions, reducing the possibilities of functional, architectural and technological choices of stakeholders. In addition, the building reuse and adaptation project must comply with rules. This affirmation is essential for a well-structured transformation intervention, but could restrict its innovation, increasing complexity and uncertainties. On the contrary, it allows in advance a natural selection of the adaptive reuse options that can be pursued. An accurate and detailed comparison between regulatory statements and master planning options has to be developed, without, at the same time, straying from the objective of hypothesizing feasible methods that can improve smart decision-making policies easily applicable and quickly achievable.

A further category detached from the first seven areas concerns the evaluation and cataloguing of the possible risks (H) that may occur before, during and after the design steps of the new architectural and functional alternative. In particular, this additional design category divides the individual constraints and hazards into three sub-attributes according to their possible appearance in the processes of monitoring, planning and recovery of the existing building and context, as well as in the phases of construction and testing of the new building organisms. Once the main categories have been identified, the next step in the structuration of DCS architecture. The seven categories described in this paragraph represent the starting point to validate the DCS rating tool to predict efficient adaptive reuse strategies for dismissed industrial sheds.

3.5.2 DCS framework and layers

The literature review process and data collection phase have brought out a considerable amount of attributes and sub-attributes that can incur in building reuse interventions. In addition, such large number of components make difficult and unintuitive for stakeholders the choices selection for the implementation of adaptive reuse strategies. It is, therefore, necessary not only the management of the components into the seven main design categories, but also the hypothesis of a diagram that allows to control and relate a large number of elements, favouring the analysis and evaluation procedures of future transformation scenarios. This section defines the architecture of the DCS, with the purpose to merge all the involved activities and scopes, into a single model. In particular, a radio-centric multicriteria system is applied in this search for the cataloguing of macro-scope, micro-scopes and activities. The DCS graph looks like a sum of five different layers. Each section allows to frame a different level of specificity of the components and the sub-attributes considered. The starting points consists in the insertion of the seven main thematic categories in the radio-centric structure. Considering the geometric conformation of the radio-centric graph, the seven main design adaptive reuse topics are placed in the center of the multicriteria model. Attributes englobe the general refurbishment and construction intervention features that can influence building adaptation processes. Sub-attributes 1 and 2, on the other hand, underline the solutions and options that increase building reuse potentials. The last layer of the DCS diagram consider possible design activities that characterise adaptive reuse interventions. This outermost sub-section outlines the construction and refurbishment solutions and actions that should be applied by stakeholders during monitoring, planning and realization steps to develop innovative and high-performing warehouses conversions aesthetically, compositionally and functionally (Figure 3.5.2-1).

The DCS model also provides an accurate classification and codification of design elements. Each category is scheduled with a letter (from A to G) and attributes, sub-attributes and activities are defined with an ID code, composed by the letter of the reference category and numbers that identify the macro-scopes and micro-scopes in which activities are inserted. In addition, to make an easier reading of the template, each layer and the single category have a different color.

The DCS design composition main goal is to clearly display in a unique diagram adaptive reuse issues, ensuring a comprehensive view of all the components taken into account to implement sustainable and feasible refurbishment interventions. The opportunity to arrange a coded thematic map that assemble adaptive reuse factors, parameters and activities not only provides to preliminary explain design flowcharts, but highlights all the relationships, risks and interferences that may arise during the strategic reuse planning.

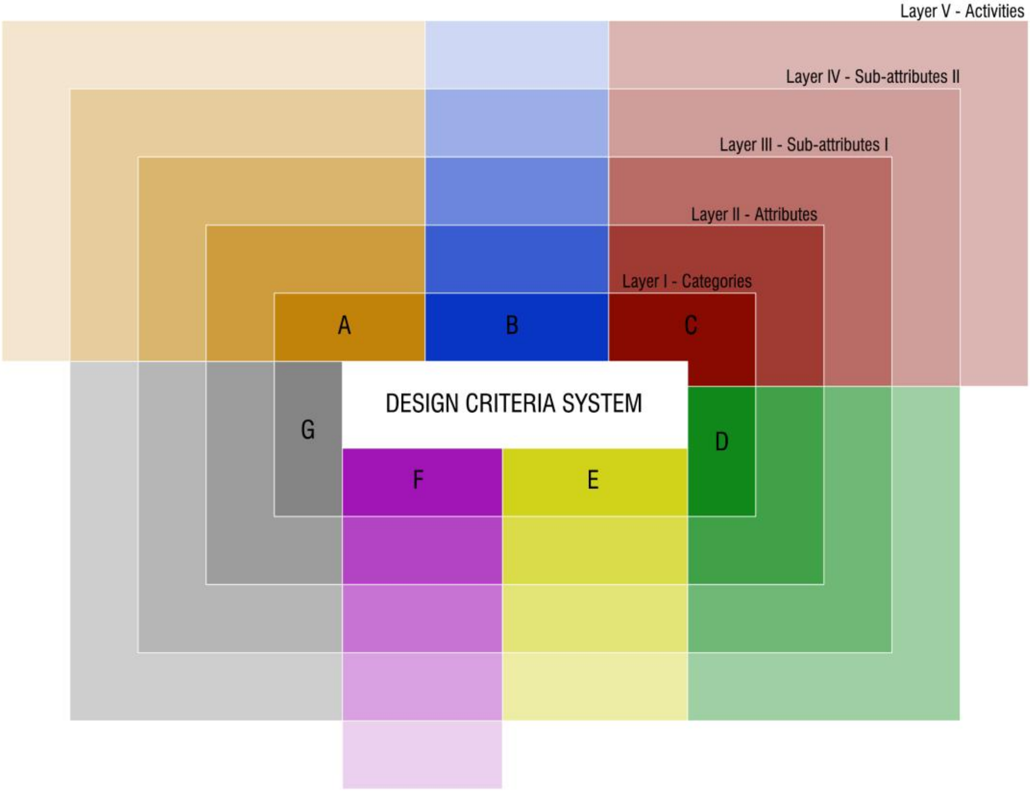


Figure 3.5.2-1 Schematic DCS radio-centric and layered structure.

3.5.3 Structuring the DCS with attributes and sub-attributes

Once the DCS architecture is developed the next step consists in the insertion of macro-scopes and micro-scopes distinguished in the seven main design categories, listed above. This interesting tool provides a gradual association of features, starting from the insertion of the attributes in relation to the seven main topic, since the characterization of the more specific layers. The use of a common language favourites the organization and storage of data, speeding up the management of components in the DCS structure. The final descriptive tables in ANNEX B (ANNEX B) list all the factors, individual tasks and risks acknowledged, dividing them according to categories and diagram layers. The radio-centric multicriteria description model is also used to better frame the design components contained in each main thematic topic (Figures 3.5.3-1; 2; 3; 4; 5; 6; 7). Different colours and labels dimension facilitate the comprehension of categories layout. Looking at the graphs structures and morphology, it is possible to notice that Physical (A), Economic (B) and Technological (D) Design Criteria are composed of a greater number of components inherent adaptive reuse processes. A second visual information that reinforces the previous consideration can be found in the chromatic tones density and in the size of the three diagrams. The proposed multicriteria system may seem complex at first glance (Figure 3.5.3-8), because it incorporates a large number of components, but the cynical arrangement of features into a well-structured design model contributes to activate efficient decision-making processes, decreasing constraints and organizational uncertainties.

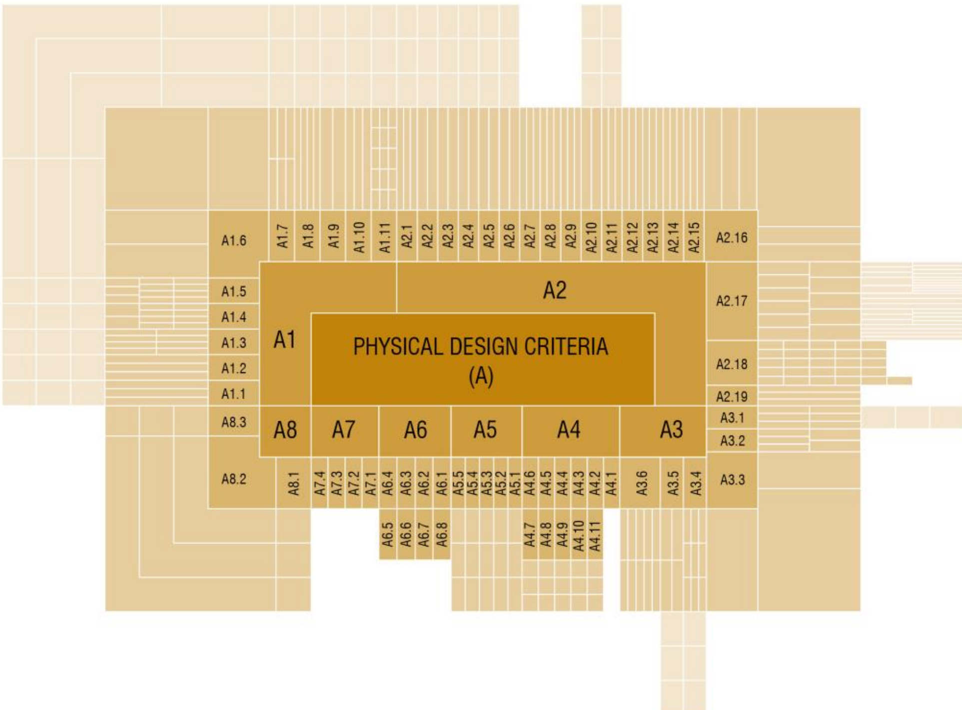


Figure 3.5.3-1 Final Physical Design Criteria radio-centric and layered structure.

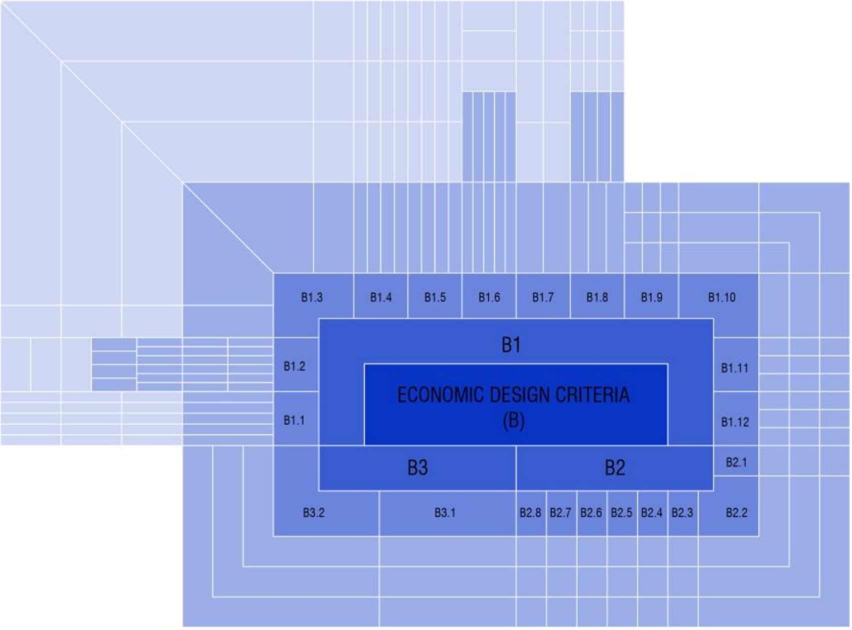


Figure 3.5.3-2 Final Economic Design Criteria radio-centric and layered structure.

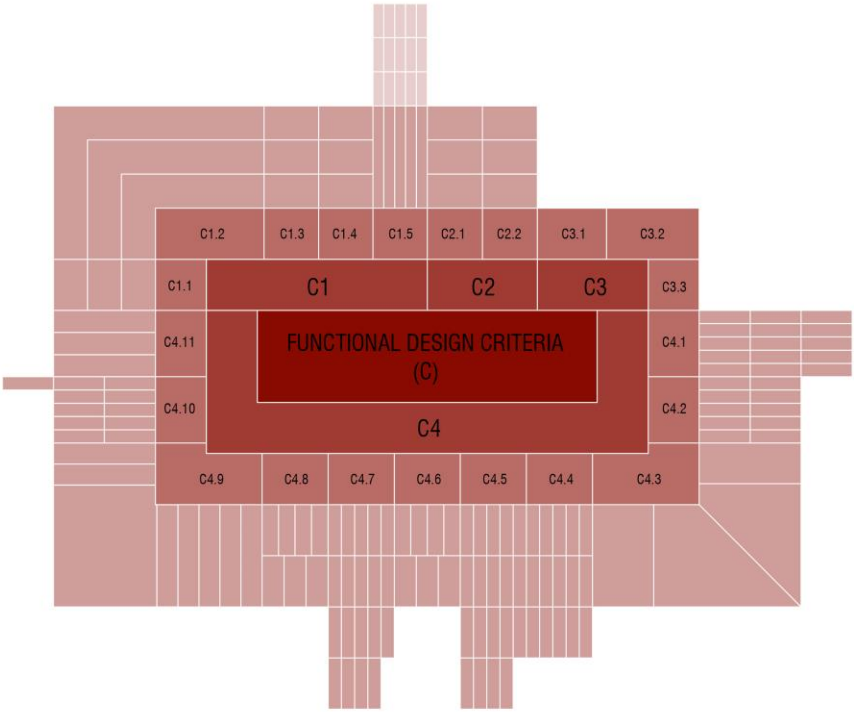


Figure 3.5.3-3 Final Functional Design Criteria radio-centric and layered structure.

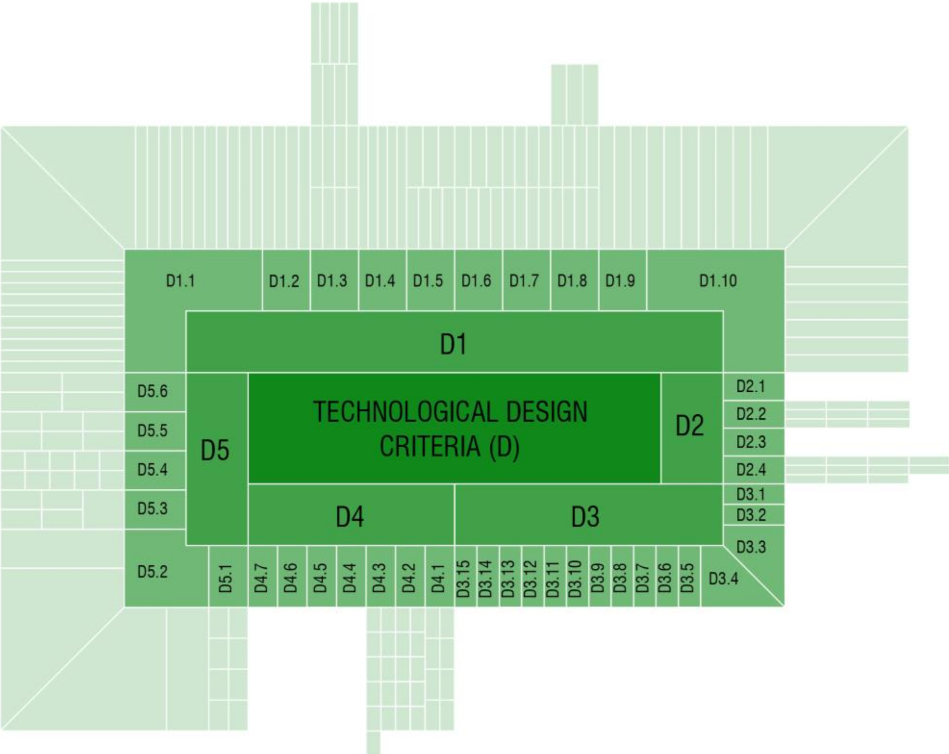


Figure 3.5.3-4 Final Technological Design Criteria radio-centric and layered structure.

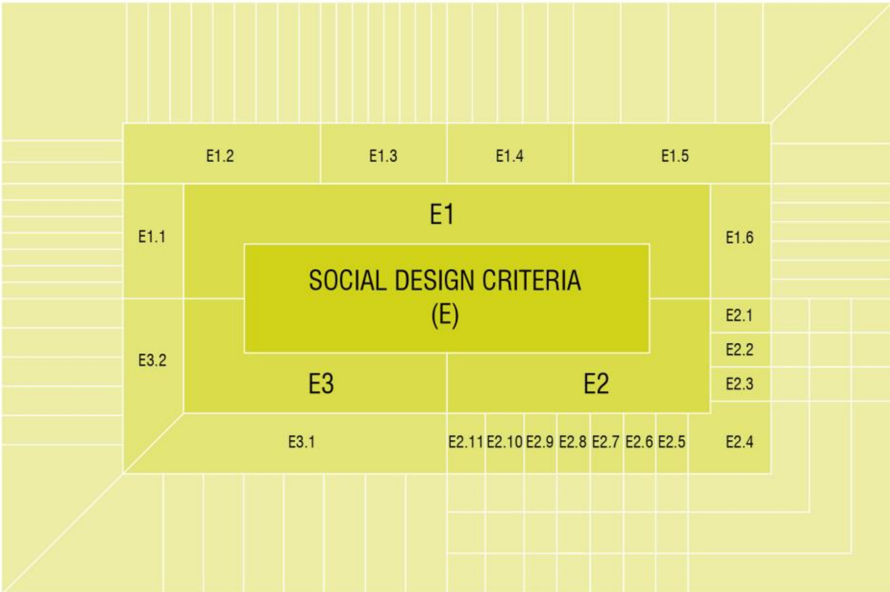


Figure 3.5.3-5 Final Social Design Criteria radio-centric and layered structure.

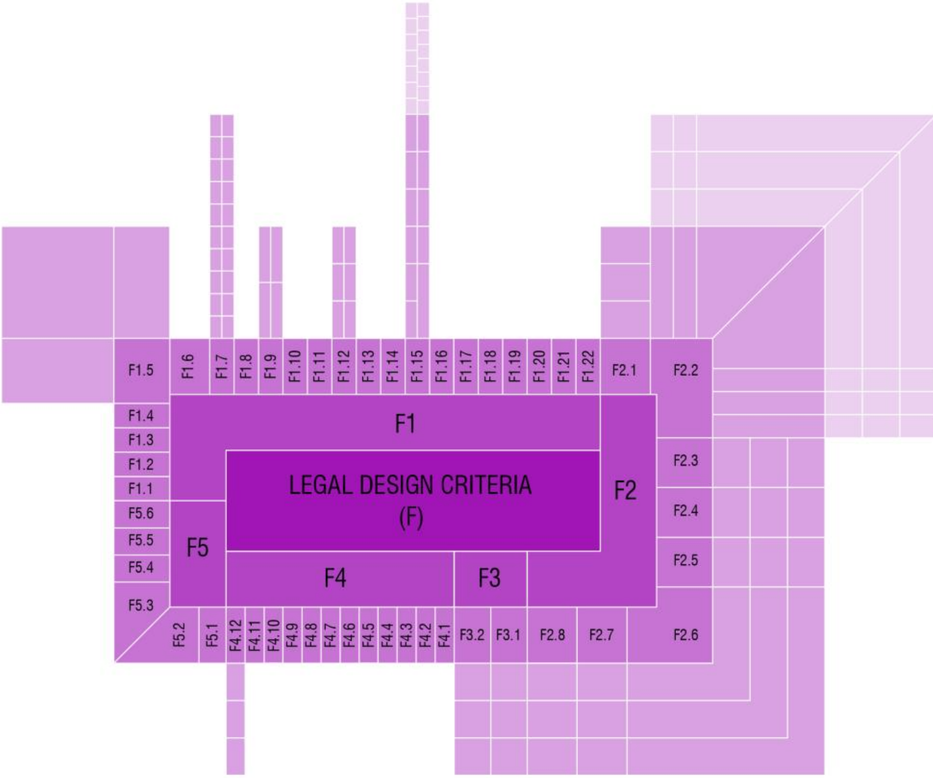


Figure 3.5.3-6 Final Legal Design Criteria radio-centric and layered structure.

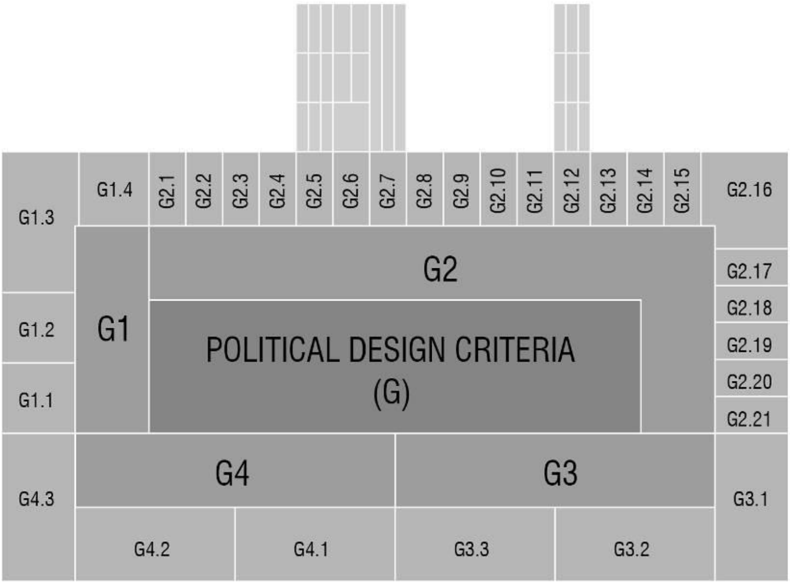


Figure 3.5.3-7 Final Political Design Criteria radio-centric and layered structure.

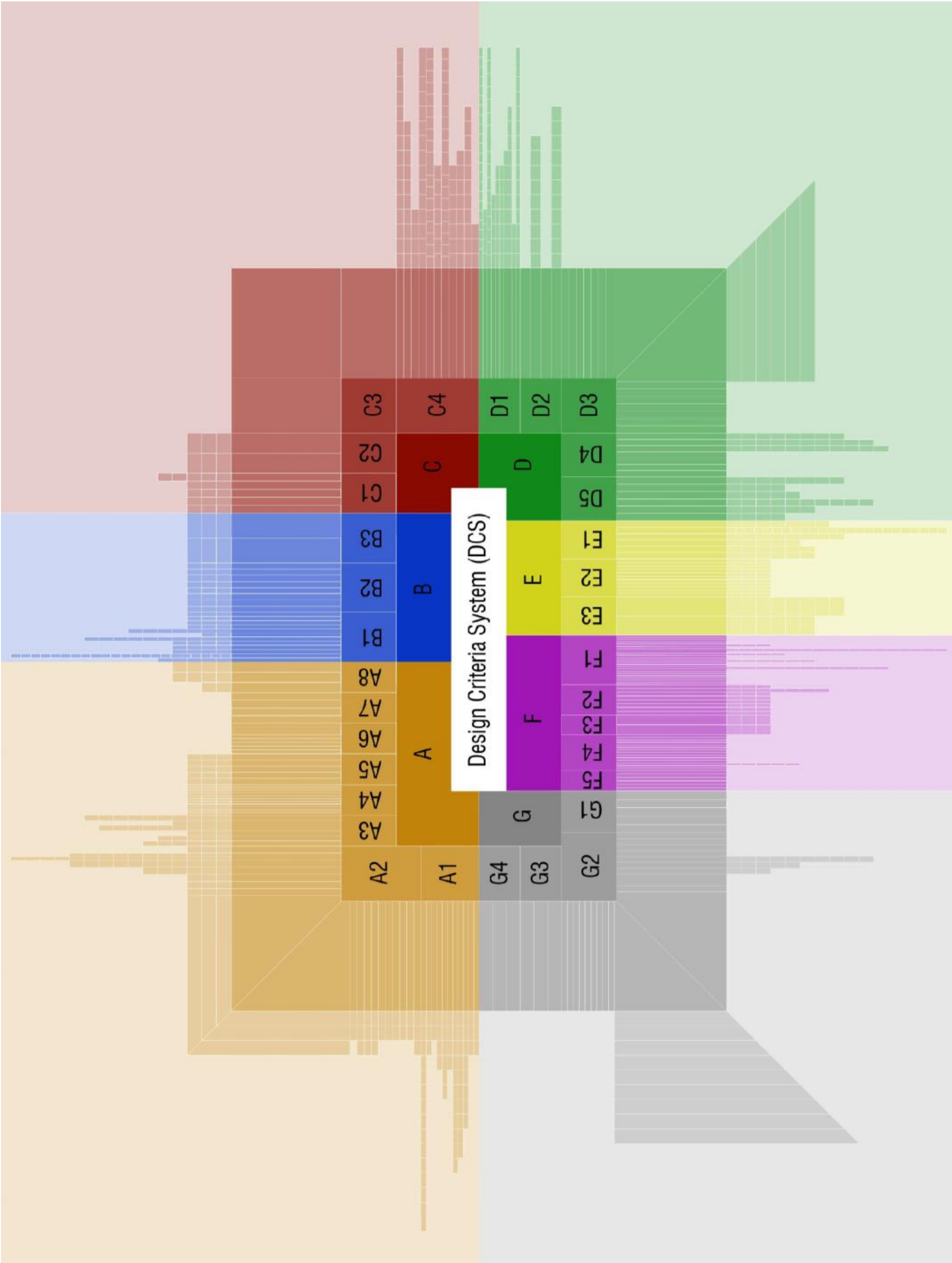


Figure 3.5.3-8 Complete Design Criteria System (DCS) architecture with the seven main categories (until sub-attributes 2).

3.5.4 Weight evaluation of parameters and risks

In the DCS methodology, the weight evaluation phase plays a fundamental role to define the impacts of each criterion in the adaptive reuse interventions. To specify the parameters ratings for the calculation of the refurbishment activities feasibility, it is necessary to assign values to each attribute included in the DCS diagram.

In particular, the DCS components weighting procedure is performed considering three main steps:

a) Formulation of interviews and surveys to stakeholders specialized in the field of construction, building adaptation, urban planning and environmental sustainability and estimation of the DCS seven main design categories (First layer of the DCS), attributes (Second layer) and risks (H) set of scores through weighted average calculation and normalization of results;
b) Structured interviews and surveys of experienced professionals in the field of construction, building adaptation, urban planning and environmental sustainability and estimation of the DCS sub-attributes 1 and 2 (Third and Fourth layers) and of individual design activities (Fifth layer) set of scores through weighted average calculation;
c) Normalization of results according to the rank of the different DCS components.

The first step to assess DCS components weights consists in the creation of a focus group of professional figures specialized in adaptive reuse and building refurbishment and in the formulation of well-organized interviews and questionnaires, querying respondents to evaluate the seven main design categories. In particular, during the PhD period, two surveys were carried out in order to understand if, over time and considering a large number of interviewees, the assessment of the importance of the seven adaptive reuse thematic areas changed. The first of the two surveys (April 2019) is carried out on a group of 77 stakeholders including Italian architects, engineers, urbanists, students and researchers. Each of the seven main design categories is rated in a range of 1 to 100. Figure 3.5.4-1 (Figure 3.5.4-1) illustrates the responses at a glance.

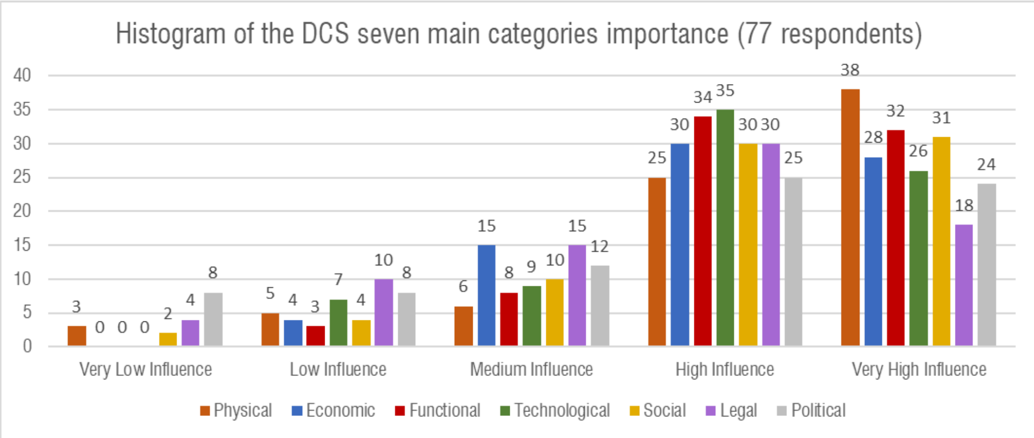


Figure 3.5.4-1 Histogram of the DCS seven main categories importance (77 respondents).

The histogram is composed on the x-axis by opinions and on the y-axis by number of respondents, having a general overview of interviewers' replies. The answers are summarised in five evaluation ranges (i.e., 0-20; Very Low Influence (VL), 21-40; Low Influence (L), 41-60; Average Influence (M), 61-80; High Influence (H), 81-100; Very High Influence (VH)) that measure how much each of the seven main categories can contribute to perceive effective adaptive reuse conversion intervention and, subsequently, quantitative data and percentages are extrapolated. The scheme shows that the vast majority of respondents (74,49%) believe that all the seven categories are important and should be considered in processes of industries adaptation. On the contrary, a limited number of stakeholders consider physical, social, legal and political aspects unimportant in adaptive reuse interventions. For estimating the categories weights, the frequency of each features for the single scale ranging are multiplying for the correspondent evaluation coefficients (e.c.) (i. e., VL(e.c.=0.0); L(e.c.=0.25); M(e.c.=0.5); H(e.c.=0.75); VH(e.c=1)). The sum of these values represents the weighting average score. A subsequent data normalization activity is developed to find the final set of weights of the main adaptive reuse categories. In particular, Physical (15.19%), Functional (15.50%) and Social (14.82%) design criteria result the most important features of DCS (Table 3.5.4-1).

Design Criteria	Very Low Influence	Low Influence	Medium Influence	High Influence	Very High Influence	Total	Weighted average	%	Normalised %
Physical	3	5	6	25	38	77	61	79.22	15.19
Economic	0	4	15	30	28	77	59	76.62	14.69
Functional	0	3	8	34	32	77	62.25	80.84	15.50
Technological	0	7	9	35	26	77	58.5	75.97	14.57
Social	2	4	10	30	31	77	59.5	77.27	14.82
Legal	4	10	15	30	18	77	50.5	65.58	12.58
Political	8	8	12	25	24	77	50.75	65.91	12.64
e.c.	0	0.25	0.5	0.75	1		Mean	74.49	

Table 3.5.4-1 Seven main categories weighted average and normalised values (I survey).

The second survey (June 2020) is achieved using an online questionnaire to 161 selected practitioners specialized in urban, architectural and engineering cultural fields. This further virtual rating scheme not only focuses on measuring the seven main design categories ranks, but also extrapolates attributes belonging to the second layer of DCS and risks weights. Although this analysis considered a very large number of people in a single focus group and is carried out a year later from the first survey, the data provided do not differ so much from the previous one. The histogram of responses, in fact, outlines that a significant number of specialized actors (70.36%) considers all the seven design categories as important and very influential in adaptive reuse processes (Figure 3.5.4-2). In addition, scores estimation is made calculating the weighting average score and normalizing the extracted outputs. The final set of normalised weights outlines that Physical (15.38%), Functional (16.24%) and Social (15.26%) are the most important design factors of adaptive reuse interventions (Table 3.5.4-2). The values of this second focus group are taking into account for the calculation of the DCS sub-attributes weights. ANNEX B (ANNEX B) reports all the obtained DCS components weights and the risks scores associated with building recovery interventions.

A similar evaluation methodology is undertaken by Conejos (Conejos, 2013b) on 93 selected Australian architects. The histogram, produced by respondents, shows that also Australian experts (85%) treat the seven main adaptive reuse categories as "important" or "critical" in building transformation processes (Figure 3.5.4-3).

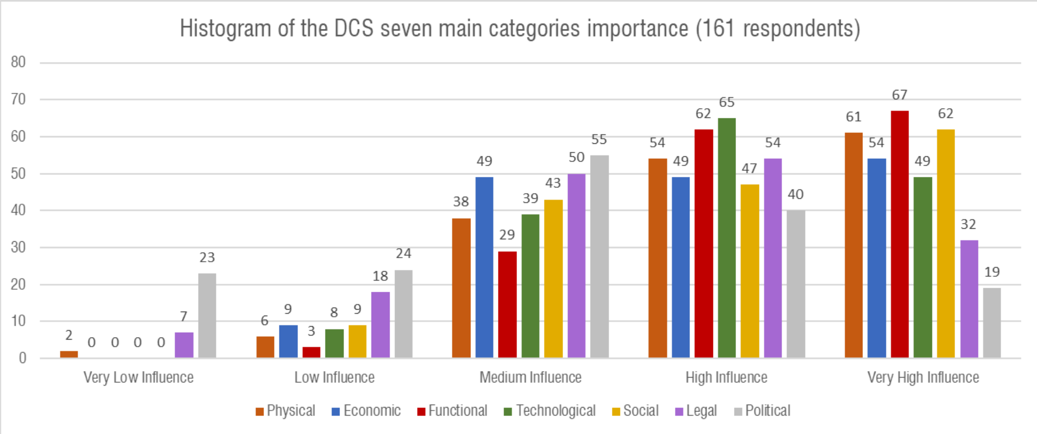


Figure 3.5.4-2 Histogram of the DCS seven main categories importance (161 respondents).

Design Criteria	Very Low Influence	Low Influence	Medium Influence	High Influence	Very High Influence	Total	Weighted average	%	Normalised %
Physical	2	6	38	54	61	161	122	75.78	15.38
Economic	0	9	49	49	54	161	117.5	72.98	14.82
Functional	0	3	29	62	67	161	128.75	79.97	16.24
Technological	0	8	39	65	49	161	119.25	74.07	15.04
Social	0	9	43	47	62	161	121	75.16	15.26
Legal	7	18	50	54	32	161	102	63.35	12.86
Political	23	24	55	40	19	161	82.5	51.24	10.40
e. c.	0	0.25	0.5	0.75	1		Mean	70.36	

Table 3.5.4-2 Seven main categories weighted average and normalised values (II survey).

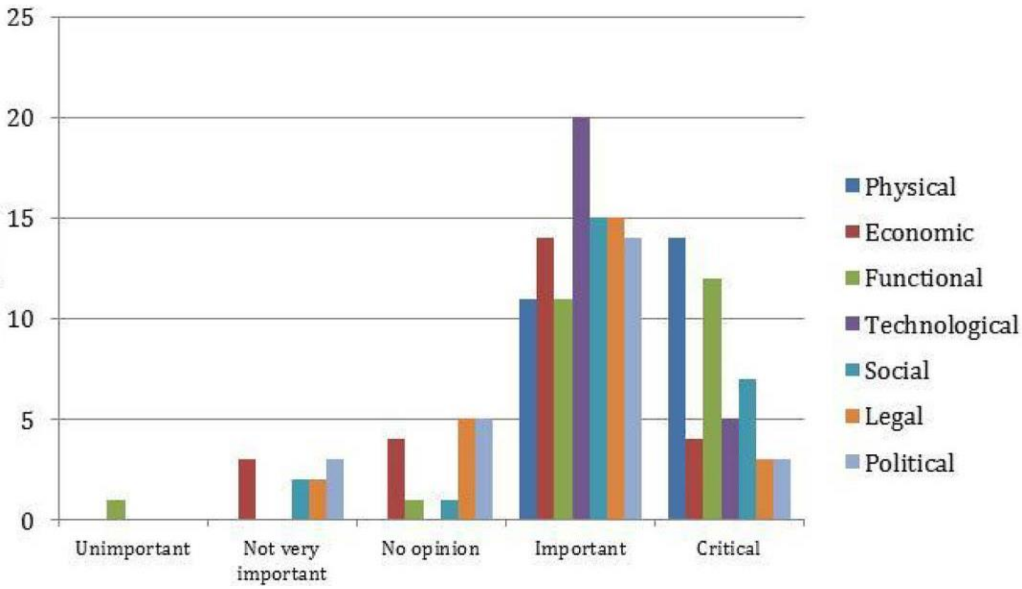


Figure 3.5.4-3 Histogram of obsolescence category importance (93 respondents) (Conejos, 2013b).

This percentage value explains the high awareness of Australian specialists on the potentials of adaptive reuse model as an efficient technique to develop sustainable policies for cities urban regeneration. Comparing the three histograms accounted in this section, most of the responses fall into the "important" or “high influence” range options. The survey results for the creation of AdaptSTAR set of weights strengthen the values obtained by the two interviews previously described, summarising Physical (16.08%), Functional (15.23%) and Social (14.37%) as the main adaptive reuse design criteria thematic field (Conejos, 2013b).

Seven well-structured and easily fillable online interviews are implemented for the weight assessment of DCS micro-scopes. The professional figures involved in the compilation of each survey are carefully selected on the basis of their scientific and cultural skills on the seven different topics of intervention and respectively: A) Physical (42 experts); B) Economic (39 experts); C) Functional (33 experts); D) Technological (31 experts); E) Social (30 experts); F) Legal (26 experts); G) Political (27 experts). The questionnaires consist of two types of response: i) sub-attributes 1 and 2 are estimated with a five-point scale ranging from Very Low Influence (VL=1); Low Influence (L=2); Average Influence (M=3); High Influence (H=4) and Very High Influence (VH=5); ii) activities are selected with multiple choice questions. For these surveys too, element weights are quantified by first calculating the weighting average score and then providing to their normalization.

The normalization phase of the subcategories, at the same time, differs from the classic mathematical process formulated for estimating the weights of the seven thematic fields. In fact, these values undergo a double normalization, since the percentage in cents of the sub-attribute is preliminary evaluated and then its real weight is calculated with respect to the value of the scope in which that specific feature is contained.

Finally, if all the criteria, attributes, sub-attributes and activities are weighted (ANNEX B) it is possible to proceed to the formulation of the adaptive reuse strategy, managing criteria in the planning stages of the building recovery table, highlighting design features relationships and estimating project effectiveness through the calculation of the feasibility coefficient (f) and the risk entity (r).

3.5.5 Management of DCS parameters in the building recovery table

Once the phases of sorting attributes, sub-attributes and activities in the DCS seven macro areas, of framing risks that may emerge during the case study monitoring, design and transformation activities and of weights quantification of multicriteria model parameters have been completed, all this data are temporally reorganized and divided into the eight different design steps, described in the general methodology section. These planning sections structure the building recovery table columns (ANNEX C-a). This scheme represents the means to manage the information of the radiocentric system in a unitary and intuitive diagram that shows, at the preliminary design stage, the components affecting adaptive reuse strategies. In particular, the elements that allow the definition and evaluation of building conversion policies and the relative risks are scanned by rows considering the seven main categories, the hierarchies identified in the DCS (categories, attributes, sub-attributes 1, sub-attributes 2, activities) and their placement in the building recovery table design steps (ANNEX C-b).
Different colour tones help the reader to easily identify each parameter references. Taking a first look at the subdivision of the criteria in the building recovery table, it is possible to notice that the evaluation, study and site monitoring phases, the characterization of the design idea and the implementation of the transformation intervention englobe a large number of DCS attributes. Another consideration can be made with regard to the greater or lesser presence of attributes belonging to one of the seven DCS scopes in the same design stage. For instance, the activities concerning physical planning micro-scopes are attributable to the monitoring of the existing building and context conditions design step and to the transformation, recovery and implementation phases. A similar situation occurs taking into account functional and technological design parameters. The components of these two macro-scopes intervene above all in the project and master plan definition phase, because they contribute to specify compositional forms, architectural features and peculiarities that each building regeneration solution has to incorporate. The building recovery table is the starting point for the graphic formulation of the transformation strategies of disused industrial sites and for the calculation of their feasibility.

3.5.6 Relationships and interactions between design parameters

Before proceeding with the formulation of adaptive reuse solutions for disused warehouses and the calculation of their feasibility, the last phase involving the process of defining design components concerns the identification, through the use of building recovery table layout, of the internal and external relationships that can be established among the DCS design elements. The purpose of this section of the methodology is to outline and differentiate the cause-and-effect relational types between attributes belonging to different thematic fields of the multicriteria system, favouring the automation of the adaptive reuse design choices selection process for the conversion of disused sheds. In particular, the scanning of criteria connections is applied on the first three layers of the radio-centric model (Categories, Attributes, Sub-attributes 1) making the conceptual schemes obtained not too complex, confusing and difficult to read.

The process is divided into two different steps: i) detection of the internal relationships between design category micro-scopes (represented in green in the ANNEX C-c diagrams); ii) highlighting of the external connections between different thematic topics of the DCS, providing a detailed framework about the key components for the formulation of the final layout of the automatic reuse strategy selection system and taking into account the iterations of activities with adaptive reuse risks (represented in red in the ANNEX C-c diagrams). To get a clear overview of the external connections between the eight main areas (including risks (H)), 28 pair comparisons are developed.

In addition, the internal and external relations of the eight design fields are further divided into two types of component comparison, described as follows:

a) Unique cause-and-effect relationships (A → B): component A, if accounted in the adaptive reuse design solution and depending on its size, influences more or less the parameter B that is included in the building conversion scenario (A occurs before B). For example, considering the parameter that measures the existing factory level of obsolescence, a high level of building and site physical degradation entails a considerable expenditure of costs, times and resources. This typology of connection between factors is also adopted to identify the possible risks that the activities could generate;

b) One-to-one cause-and-effect relationships (A ←→ B): They occur when two factors A and B affect each other's building recovery activities. If factor A is considered by the adaptive reuse solution, also the parameter B intervenes in the assumed transformation scenario (A and B are activated at the same time). For instance, interventions that encompass spatial and compositional building layout certainly take into account the functional aspects of flexibility, disassembly, convertibility and usability of the modified surfaces and volumes hypothesized in the adaptive reuse option.

At the same time, it is fundamental to point out that not all the contextualized activities in the building recovery table always take part in adaptive reuse processes, since the individual case studies tested have different physical, morphological, social, technological and political characteristics that require the development of specific strategic design solutions. In addition, a set of descriptive and compositional rules is adopted to strengthen the comparative criteria analysis, enhance more effective, reliable and understandable thematic schemes and characterize the building recovery table.

The main points are described and listed as follows:

1) Each individual category/subcategory is inserted once in the building recovery table with the exception of stakeholders who can actively participate in multiple development phases of building adaptation interventions, and municipal and regional regulations and plans that are considered as supporting documents useful for the design decisions and implementation of accurate analyses concerning the planning idea definition, industrial site conversion solution realisation and future maintenance activities of its components;

2) Each attribute/sub-attribute is associated with one of the eight phases of the building recovery table;
3) Each individual category/subcategory can be related to one or more parameters also belonging to different design topic;
4) Criteria/sub-criteria are related to each other based on their hierarchy and rank within the DCS, starting from the main categories up to sub-attributes 1. For example, an element belonging to the "attribute" layer can affect a "sub-attribute 1" component by a unique cause-and-effect relationship, but, at the same time, the inverse hypothesis cannot happen;
5) The chart reading is from left to right and from the main categories to the individual tasks;
6) Each category/subcategory is catalogued with an ID code consisting of an initial letter identifying the relative main category and a maximum of 4 numbers based on the rank of the subcategory in the DCS structure;
7) Each category/subcategory is characterized by different colours.

Once all the relationships between the different scopes and the compositional and hierarchical rules to respect in the building recovery table structure are defined, the information obtained allows to proceed with the development of the adaptive reuse strategy.

3.6 Development of adaptive reuse strategies and evaluation of project feasibility at the preliminary design stage

The automatic formulation and schematization of adaptive reuse policies for disused historical and contemporary industrial warehouses takes place through the interpolation of the input data contained in the building cataloguing sheet with the DCS components and activities divided in multiple design steps in the building recovery table. The main goal of this section of the methodology consists in the extrapolation of effective and feasible adaptive reuse strategies for the improvement of smart urban regeneration procedures on disused marginal industrial contexts, as well as in the formulation of intuitive and functional conceptual guidelines and maps that simulate, at the preliminary planning stage, the adaptation factors that intervene during building transformation operations on the basis of architectural and functional hypothesis emerged from the application of MCDMA.

In particular, this final section of the methodology is divided into four sub-sections:

1) Accurate morphological-architectural description of the most effective and adaptable design solution for factory transformation, deduced from the application of decision support models and subsequent compilation of the building cataloguing sheet labels. The information, included in the identikit table of the existing and adaptive reuse scenario, are closely related to some of the components contained in the seven main DCS categories (Physical Design Criteria - A, Functional Design Criteria - C and Social Design Criteria - E), and to any risks deductible from the site survey activities carried out. Figure 3.6-1 (Figure 3.6-1) illustrates the interactions between the case study descriptive sheet labels and the attributes contained in the DCS. The values and information of the industrial site identikit scheme represent the input data to be inserted into the building recovery table to implement adaptive reuse strategies;
2) Insertion of input data in the building recovery scheme and formulation of the adaptive reuse strategy. This procedure, once the parameters connected with the building cataloguing sheet have been identified, allows the automatic extrapolation of the sequence of conversion and recovery activities of derelict warehouses, comparing the internal, external, unique and one-to-one cause-and-effect relationships contained in ANNEX C-c. In addition, the diagram graphically shows the final flowchart, highlighting the criteria that intervene in the different phases of the building transformation process according to the characteristics of the explored reuse scenario;

General Data			
Building/site name		Climatic zone	
City		Orientation	A6
Region		Number of entrances	
Nation		Landscape quality	A3.5.4
Address		Building Size	A5
Site location		Site surface (m²)	A5.3
Years of construction and dismission		Building surface (m²)	A5.1
Distance from city center		Total volume (m³)	A5.2
Number of existing buildings		Level of maintainablity	Site = A8.1
Number of historic buildings			Context = A8.2
Building structural typology			Infrastructures = A8.3
Green areas (m²)		Reclamation interventions	A7
Public space (m²)		Glazed surface	A5.4

Existing buildings data					
Building Surfaces (m²)	Building 1		Volumes (m³)	Building 1	
	Building 2			Building 2	
	Building 3			Building 3	
Heights (m)	Building 1		Number of floors	Building 1	
	Building 2			Building 2	
	Building 3			Building 3	

Physical analysis					
Existing abandoned industrial site					
Level of decay	Site	A3	Dampness	A1.8	Presence of constraints
	Buildings	A1	Pests	A1.9	
	Materials	A1.2	Natural attack	A1.10	
	Structures	Pillars = A1.3.1	Existing plants	A1.4.n	
		Beams = A1.3.2			
		Walls = A1.3.7			
		Vertical connections = A1.3.8			
		Foundation = A1.3.6	Site conditions	Soil type	A3.2
		Floor = A1.3.3		Presence of vegetation	A3.3
		Roof = A1.3.4		Level of traffic	Car = A3.4.1
		Joints = A1.3.5			Bike = A3.4.5
		Facade = A1.1			Bus = A3.4.9
	Plants	A1.4			Camion = A3.4.2
	Technologies	A1.6			Train = A3.4.7
	Functional decay	Parking areas = A1.7.6			Pedestrian = A3.4.6
		Space dimensions = A1.7.1, A1.7.3			A3.4.3, A3.4.4, A3.4.8
		Flows management = A1.7.2, A1.7.4, A1.7.5		Level of pollution	Environmental=A3.1.1
	Green areas	A3.3			Acoustic=A3.1.2
	Context	A3.5			Water=A3.1.3
Level of humidity	A4.1				Soil=A3.1.4
Presence of asbestos					Light=A3.1.5
Lack of building parts					Air=A3.1.6

Project					
Buildign transformation interventions	Cladding	A2.1		Subtraction	A2.6
	Interior design	A2.4		Demolition	A2.8
	Addition	Connection	A2.2	Envolve	A2.11
		Merge	A2.3	Outside	A2.12
		Elevation	A2.7	Connection through public space	A2.14
		Intrusion	A2.9	Landscape and urban art	A2.15
		Stack	A2.10		
		Duplication	A2.13	Excavation	A2.19
N. of new buildings	A2.18		M² added surfaces		
N. of refurbished buildings	A2.17		M³ added volumes		
N. of demolished buildings			Insertion of new openings		

New buildings project data					
Building Surfaces (m²)	Building 1		Volumes (m³)	Building 1	
	Building 2			Building 2	
	Building 3			Building 3	
Heights (m)	Building 1		Number of floors	Building 1	
	Building 2			Building 2	
	Building 3			Building 3	

New buildings project data					
Building Surfaces (m²)	Building 1		Volumes (m³)	Building 1	
	Building 2			Building 2	
	Building 3			Building 3	
Heights (m)	Building 1		Number of floors	Building 1	
	Building 2			Building 2	
	Building 3			Building 3	
Functional analysis			**Social analysis**		
Space flexibility and convertibility	C2.1	C2.2	Stakeholders involved	E1.1, E1.2, E1.3, E1.4, E1.5	
Main functions	Function category	Specific function			
	C4.n	C4.n.n			
N. of services					
Level of accessibility and connectivity					
Spatial flow management	C1.n		Users	E1.6	
Dismantlability	C3				
Project building total surface (m²)					
Project green areas (m²)					
Project public spaces (m²)			Population needs	E3.1	
Distance from points of interest	Points of interest	Distance (Km)			
			Site importance for society	E2.1, E2.2	
			Usability and liveability	E2.4, E2.6, E2.8	
Building connectivity	Points of interest	C1.5.1	Site aesthetic identity	A2.3, E2.7	
	Parking areas, public spaces and green areas	C1.5.2	Site attractiveness	E2.9	
	City centre	C1.5.3	Relation society-environment-building	E2.5	
	Waterfront	C1.5.4	Social inclusion	E2.10	
	Main services	C1.5.5	Social participation	E2.11	
Other information					
Economic feasibility	B2.8	Political feasibility		Investments	B3.2, B3.3
Applied materials	D1.n.n	Implemented technologies	D3.n.n, D4.n.n, D5.n.n	Security and safety systems	D2.n.n
S.W.O.T. Analysis					
Strenghts			**Weaknesses**		
Opportunities			**Threats**		
Risks					
H					

Figure 3.6-1 Data links between building cataloguing sheet labels and DCS attributes.

3) Calculation of the feasibility coefficient (f) of the industrial refurbishment and transformation strategy. The sum of the parameters that structure the strategic criteria flowchart generated from the building recovery table ensures to calculate the final feasibility value of the specific adaptive reuse intervention.

This quantitative evaluation parameter estimates the reliability, adaptability and potentials of the selected project scenario through MCDM approaches for the activation of innovative and sustainable urban regeneration policies of the treated abandoned industrial area. In particular, depending on the score obtained in a value between 1 and 100, the feasibility coefficient of adaptive reuse intervention can fall into one of the five ranges, indicated below, that classify the adaptive reuse solution efficiency (Figure 3.6-2):

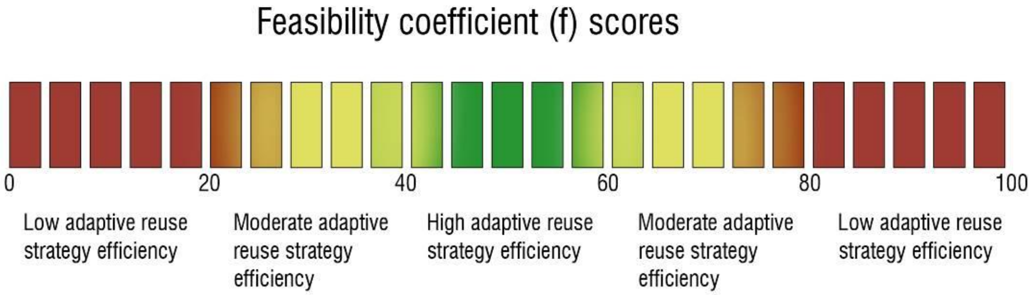


Figure 3.6-2 Feasibility coefficient (f) score graph.

a) Range 0-20: ineffective adaptive reuse option due to the participation in the strategy of a limited number of parameters. The existing industrial building presents a low level of degradation and the adaptation process is not economically expensive, but it may not respect the bureaucratic and legislative aspects, or it may not be complete and performing from the technological and functional point of view;
b) Range 20-40: medium-effective building refurbishment intervention that considers a fair number of design, functional and technological parameters. The disused shed incorporates a medium-low level of obsolescence and the transformation is cost-effective, but may not meet all of the stakeholders' current needs or ensure optimal indoor comfort standards and building quality;
c) Range 40-60: effective adaptive reuse scenario in terms of performances, technologies, functional mixitè and building indoor and outdoor quality.

The abandoned industrial site, at the same time, has a medium-low level of obsolescence and higher intervention costs due to the inclusion in the strategy of more avant-garde and passive hi-tech solutions and safety and security actions;

d) Range 60-80: averagely pursued industrial reuse solution for the presence of medium-high existing decay conditions and, therefore, of high costs of recovery and implementation of sustainable warehouses conversion interventions. This medium-effective strategic typology entails the selection of a large number of reuse activities, as well as multiple technological, material and structural options to guarantee liveability standards of indoor spaces;

e) Range 80-100: building conversion option that is not at all punishable in economic terms, since the existing industrial site presents high and advanced physical and structural degradation conditions. This scenario implies a high use of social, technological and financial resources, as well as it could require environmental remediation interventions, greatly increasing the project realisation times.

4) Calculation of the risk entity (r) of the industrial building refurbishment process. The risk coefficient measures how much the constraints that may occur during the monitoring, design, management approval and construction adaptive reuse phases affect the feasibility, innovation and usability of the proposed conversion strategy. The final score of the risk entity, ranging from 0 to 100, is evaluated by mathematical sum of weights of risk parameter listed in the building cataloguing sheet and highlighted in the building recovery table flowchart based on the identified unique external relationships (Figure 3.6-3). In particular, low values of the risk coefficient ($r \leq 50$) correspond to a limited presence of negative events that can compromise the effectiveness of adaptive reuse intervention. At the same time, high ranges of r ($r > 50$) mean that, although the solution can be sustainable and technologically innovative, the

physical level of decay of the existing shed structure and site, the non-compliance of stakeholders regarding the respect of urban standards, technical-construction errors and delays in the conception, approval and realisation of reuse processes do not allow to carry out operable building adaptation policies on that particular decommissioned industrial marginal context.

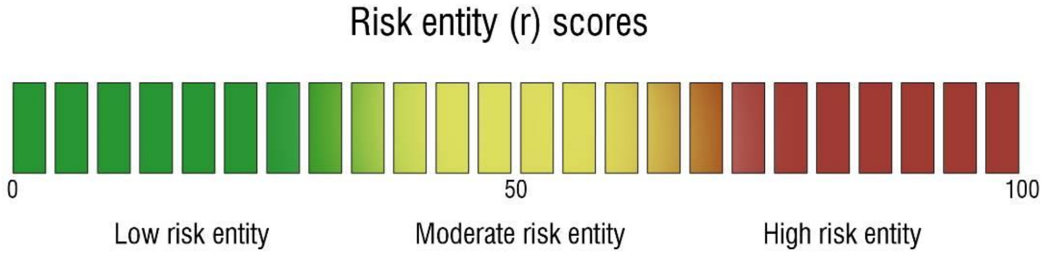


Figure 3.6-3 Risk entity (r) score graph.

The four steps of the methodology promote an innovative and versatile approach to simulate strategic and technological solutions for urban regeneration of disused industrial volumes, allowing a preliminary evaluation of the actions for the development of smart and consistent adaptive reuse guidelines. Moreover, the use of schematic thematic diagrams and cataloguing tables that summarise design solutions and peculiarities facilitate a better classification of the parameters recurred in the building conversion process, as well as highlight the factors that most affect industrial reuse transformation strategies.

3.7 Building adaptation costs calculation

A small part of the research is reserved for the calculation of the total cost of the hypothesised adaptive reuse solutions for the conversion of disused industrial contexts. The costs quantification related to the refurbishment and new construction activities of the selected sustainable building adaptation options is essential to assess whether a given morphological-compositional strategy can guarantee not only conditions of design and temporal feasibility, but also economic viability. In particular, the preliminary economic evaluation is carried out through the identification, in regional and national price lists, of parametric costs based on building types and additional technical conditions depending on the complexity of the refurbishment and construction processes.

In this research, two different bibliographic sources are consulted: i) the resolution of the Regional Council no. 2081 of 3 November 2009 lists the monetary values for new construction and sustainable building refurbishment activities, outlining basic and additional costs (Decreto di Giunta Regionale n.2081, 2009) and ii) the Bulletin Prices of Building typologies of the College of Engineers and Architects of Milan provides an accurate documentation about costs for completed works considering a series of scenarios with different functional use (Collegio degli Ingegneri e Architetti di Milano, 2019). Table 3.7-1 lists the prices per square meter found in the sources mentioned above, normalising them on the basis of the current industrial warehouses cost index (September 2020) formulated by the National Statistical Institute (www.dati.istat.it). The preventive estimation process of the final adaptive reuse design solution price is developed considering the values of the parametric costs present in the table that best suit context and buildings characteristics, as well as the complexity and innovativeness of the adopted option. In addition, depending on the quantitative surface data reported in the building cataloguing sheet, it is possible to distinguish the sites areas to be regenerate and the square meters of new project spaces. These information are subsequently multiply respectively with the selected recovery and construction parametric costs. The sum of the average economic values obtained by the two multiplications is the final cost of the assumed adaptive reuse solution. The economic data provided by this analysis complete the preliminary information framework on the feasibility of the functional conversion process for industrial abandoned volumes adaptation. The partnership of quantitative data and diagrams describing the construction design policies delayed over time ensure an effective and exhaustive preliminary strategic simulation of future scenarios of urban redevelopment to transform abandoned marginal industrial factories.

Building refurbishment interventions costs	Basic parametric costs €/sqm	Normalised construction cost index of an industrial warehouse September 2020 - 103.7 (ISTAT)	Normalised parametric costs €/sqm
Regional decree n.2081 / 03-11-2009		93.9	
Basic costs	387.27	109.8	425.22
Building recovery costs to assess sustainability issues	480.22	109.8	527.28
Costs for additional technical conditions	669.98	109.8	735.64
Additional charges	951.37	109.8	1044.60
Building typologies list prices (DEI, 2019)		103.4	
Renovation of 3 industrial buildings for office use	1762	100.3	1767.29
Renovation and reclamation of existing buildings	839	100.3	841.52
Building construction costs			
Regional decree n.2081 / 03-11-2009		93.9	
Basic costs	646.18	109.8	709.51
Building recovery costs to assess sustainability issues	801.26	109.8	879.78
Costs for additional technical conditions	878.8	109.8	964.92
Additional charges	1300.62	109.8	1428.08
Building typologies list prices (DEI, 2019)		103.4	
Shed class 500 - Flat cover	488	100.3	489.46
Shed class 500 - Double slope cover	474	100.3	475.42
Shed class 1600 - Flat cover	393	100.3	394.18
Shed class 1600 - Double slope cover	366	100.3	367.10
Shed class 5000 - Flat cover	353	100.3	354.06
Shed class 5000 - Double slope cover	314	100.3	314.94
Complete industrial complex - Type A	913	100.3	915.74
Complete industrial complex - Type B	1036	100.3	1039.11
Multi-level industrial building	783	100.3	785.35
Complete industrial complex - Type C	752	100.3	754.26
Improvement of seismic resistance	10.75	100.3	10.78

Table 3.7-1 Parametric costs distinguished in refurbishment intervention costs and building construction costs.

3.8 Validation of the DCS via AdaptSTAR and ARP Models

To strengthen and verify the consistency and reliability of the multicriteria design model described in the previous paragraphs of methodology, the case studies and adaptive reuse solutions hypothesized are evaluated through the use of two patented and easy-to-use analysis methods. These two applications quantify the reuse

potentials of a disused building through the estimation and comparison of obsolescence and design criteria.
The first validation analysis of the DCS results consists in the measure of the ARP score (Langston & Shen, 2007; Langston et al., 2008; Langston, 2012). The ARP Model developed by Langston et al. (Langston et al, 2008) is an index method that identifies and ranks adaptive reuse potentials in existing buildings. Using this application to evaluate a given dismissed industrial structure, the actors involved in the project must estimate of Building's Physical Life (L_p) and Building's Age (L_b). The definition of L_b is straightforward to identify. On the contrary, L_p is an estimated value that refers to the length of time that a building should physically last. Literature suggests using physical life as a value equal to 100 years (Langston et al., 2008). At the same time, if the building is historic, L_p can be increased to 150 years or 200 years.

The second step of the ARP Model assesses and describes seven categories of obsolescence advanced as a suitable method in order to calculate objectively the useful life of the building (L_u). All the criteria obsolescence variables are estimated by assessors and summarised as follows:

1) O_1 = Physical Obsolescence: it is measured by a detailed survey of maintenance policy and building performance. A values range scale, between 0% to 20%, is developed to highlights buildings that can receive a high maintenance budget (0% reduction) from scenarios with low maintenance investments (20% reduction);
2) O_2 = Economic Obsolescence: this parameter can be estimated considering the building localization in urban contexts. A value range scale is implemented to distinguish buildings sites in populated areas (0% reduction) from structures located in low density districts (20% reduction);
3) O_3 = Functional Obsolescence: this category represents the flexibility embedded in the intrinsic spatial building's design. A value range scale differentiates

buildings with low churn cost (0% reduction) form contexts with a high churn cost (20% reduction);

4) O_4 = Technological Obsolescence: it is evaluated considering building's use of operational energy. A value range scale is implemented to separate structures with low energy demand (0% reduction) from envelopes that require a high energy demand (20% reduction);
5) O_5 = Social Obsolescence: this feature can be measured by relating hypothesised functions with market influence. A value range scale distinguishes buildings that could be fully owned and occupied spaces (0% reduction) from constructions with fully rented spaces (20% reduction);
6) O_6 = Legal Obsolescence: this criterion evaluates building original design quality. A value range scale is developed according to high (0% reduction) or low (20% reduction) buildings quality;
7) O_7 = Political Obsolescence: it measures the community and public interest in the adaptive reuse project. In the case of political factor, the value range scale fluctuates between -20% (favourable and supportive environment) and +20% (unfavourable and inhibiting environment), where a 0% score represents apathy.

Once all the seven categories of obsolescence are evaluated by stakeholders, the next step provides to the elicitation of L_u. The Useful Life is determined using the discounting method (Langston et al., 2008; Wilkinson et al., 2014), where the discount rate is the sum of obsolescence variables in decimal form on a per annum basis. Equation 3.8-1 (Eq. 3.8-1) determines the Useful Life (L_u):

$$\text{Useful life}\,(L_{\text{u}}) = \frac{L_{\text{p}}}{\left(1 + \sum_{i=1}^{7} O_i\right)^{L_{\text{p}}}} \qquad (3.8\text{-}1)$$

where L_p denotes physical life (years) and O_1, O_2, O_3, O_4, O_5, O_6 and O_7 represents the % as decimal p. a. of the seven obsolescence variables.
Subsequently, the ARP Model assesses Effective Useful Life (EL_u), Effective Building Age (EL_b) and Effective Physical Life (EL_p) multiplying L_u, L_b and L_p by 100 and dividing each by L_p. The feasible ARP zone is bounded by the Decay Curve (where x is in the range 0-100) defined in the equation 3.8-2 (Eq. 3.8-2). The shaded region in the graph illustrates the space in which ARP scores are plotted (Figure 3.8-1).

$$y = 100 - \frac{x^2}{100} \qquad (3.8\text{-}2)$$

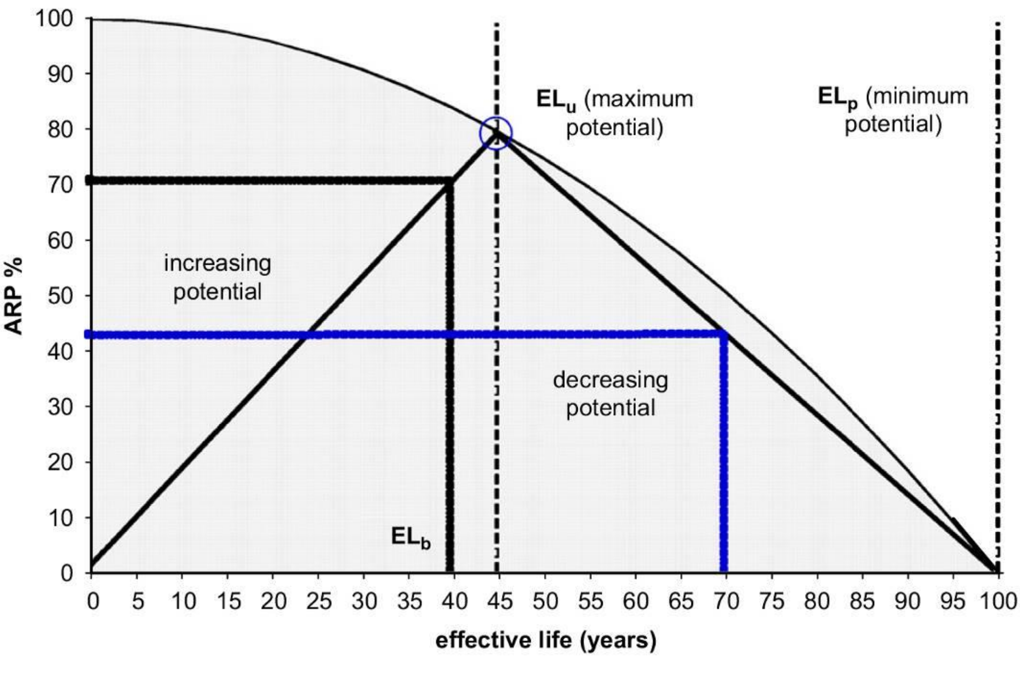


Figure 3.8-1 ARP Model concept (Langston et al., 2008).

$ARP_{INCREASING}$ and $ARP_{DECREASING}$ formulae (Eq. 3.8-3; 4) show the linear progression of increasing ARP towards the maximum point at EL_u and decreasing ARP from the maximum point at EL_u towards zero ARP value (x = 100). Equation 3.8-3 (Eq. 3.8-3) is applied when $EL_b \leq EL_u$ and formula 3.8-4 (Eq. 3.8-4) is used when $EL_b \geq EL_u$.

$$\mathrm{ARP}_{(\mathrm{increasing})} = 100 - \frac{(\mathrm{EL}_\mathrm{u}^2/100)}{\mathrm{EL}_\mathrm{u}} \times \mathrm{EL}_\mathrm{b} \quad (3.8\text{-}3)$$

$$\mathrm{ARP}_{(\mathrm{decreasing})} = 100 - \frac{(\mathrm{EL}_\mathrm{u}^2/100)}{100 - \mathrm{EL}_\mathrm{u}} \times (100 - \mathrm{EL}_\mathrm{b}) \quad (3.8\text{-}4)$$

ARP score above 50 signifies that the building analysed has high potential for adaptive reuse, while values in the range 20-49 display moderate building conversion effectiveness, and values ranked between 1-19 show structure low potential of transformation. ARP values upper to 85 mean that building adaptation policies should strongly promoted.

A second multicriteria tool that provides a robust estimation of adaptive reuse solutions potentials is the AdaptSTAR Model (Conejos et al., 2013; 2015). This weighted checklist of design strategies allows to calculate future successful adaptive reuse intervention of industrial abandoned factories. It is composed of 26 design criteria with weighted percentages (Table 3.8-1) organised into the seven main categories (Physical, Economic, Functional, Technological, Social, Legal and Political). The calculation of the adaptive reuse solutions hypothesized for each research industrial site is developed using the patented virtual platform of the AdaptSTAR Scan System (www.adaptstarinc.com).

This online evaluation tool is divided into two different sections:

a) the first section consists in the creation of the building profile, inserting descriptive and logistical information identified already in the previous methodology analysis step and in the building cataloguing sheet;
b) the second part calculates the AdaptSTAR score, evaluating, on the basis of the information that emerged from the site surveys and inspections, master plans of the existing layout, cartographies, documents and building adaptation solution selection phases, the 26 weighted design independent criteria that make up the multicriteria model.

Category	Criterion	Description
Physical (long life)	Structural Integrity and Foundation	Building structural design to host uses and settlements of substrata
	Material Durability and Workmanship	Craftmanship quality and conservation of existing materials
	Maintainability	Building's capability to preserve operational resources
Economic (location)	Density and Proximity	Distances from points of interest and population local density
	Transport and Accessibility	Connection with services and city districts
	Plot Size and Site Plan	Site dimensions and planning phases
Functional (loose fit)	Flexibility and Convertibility	Space capability to change acconrding to contemporary society needs
	Disassembly	Modularity and options to reuse and recycle existing building components
	Spatial Flow and Atria	Mobility, management of people flows and presence of open areas
	Structural Grid	Building interchangeability
	Service Duct and Corridors	Vertical connection and circulation
Technological (low energy)	Orientation and Solar Access	micro climate characteristics and temperatures measures
	Glazing and Shading	Sunlight control and shading technologies
	Insulation and Acoustic	Thermal and acoustic performances
	Natural Lighting and Ventilation	Optimisation of airflow and efficient lighting systems
	Energy Rating	Environmental performances and energy consumption
	Learn and Obtain Feedback on Building Performance and Usage	Monitor and control of building comfort indoor through smart technologies
Social (sense of place)	Image and History	Building historic values and iconicity
	Aesthetics and Townscape	Architectural beauty and coherence with the built environment
	Neighbourhood and Amenities	Local community and existing local services
Legal (quality standard)	Standard of Finish	Provision for high standard workmanship
	Fire protection and Disability Access	Fire safety and facilities
	Occupational Health, Indoor Environmental Quality (IEQ), Safety and Secutrity	Society health, risks management and passive surveillance design
Political (context)	Ecological Footprint and Conservation	Measure of human carrying capacity and preservation charts
	Community support and Ownership	Stakeholders participation and collaborative commitment
	Urban Master Plan and Zoning	Land patterns and building integration in urban skyline

Table 3.8-1 AdaptSTAR building adaptive reuse design criteria (Conejos et al.,2013).

The score selection phase must relate to the latent conditions of the case study before the adaptive reuse conversion intervention. Each attribute is evaluated by answering the question "How do you judge the following statements for the above building/facility?", choosing from five different values: i) 1-Strongly disagree; (ii) 2-Disagree; (iii) 3-Neutral; (iv) 4-Agree; v) 5-Strongly agree. The detailed ranking approach, applied in this research, allows to determine the importance of each criterion in building adaptation and transformation processes according to the existing context features. Table 3.8-2 (Table 3.8-2) shows the weights of the parameters according to the answer given for the calculation of the AdaptSTAR score.

Category	Criterion	1	2	3	4	5
Physical (long life)	Structural Integrity and Foundation	1.12	2.23	3.35	4.46	5.58
	Material Durability and Workmanship	1.07	2.13	3.2	4.26	5.33
	Maintainability	1.03	2.07	3.1	4.14	5.17
Economic (location)	Density and Proximity	0.89	1.79	2.68	3.58	4.47
	Transport and Accessibility	0.9	1.81	2.71	3.62	4.52
	Plot Size and Site Plan	0.88	1.76	2.65	3.53	4.41
Functional (loose fit)	Flexibility and Convertibility	0.68	1.37	2.05	2.74	3.42
	Disassembly	0.59	1.18	1.78	2.37	2.96
	Spatial Flow and Atria	0.6	1.2	1.8	2.4	3
	Structural Grid	0.61	1.21	1.82	2.42	3.03
	Service Duct and Corridors	0.56	1.13	1.69	2.26	2.82
Technological (low energy)	Orientation and Solar Access	0.56	1.12	1.68	2.24	2.8
	Glazing and Shading	0.51	1.02	1.52	2.03	2.54
	Insulation and Acoustic	0.5	1	1.49	1.99	2.49
	Natural Lighting and Ventilation	0.53	1.07	1.6	2.14	2.67
	Energy Rating	0.46	0.92	1.39	1.85	2.31
	Learn and Obtain Feedback on Building Performance and Usage	0.41	0.82	1.22	1.63	2.04
Social (sense of place)	Image and History	0.94	1.88	2.81	3.75	4.69
	Aesthetics and Townscape	1.01	2.02	3.02	4.03	5.04
	Neighbourhood and Amenities	0.93	1.86	2.78	3.71	4.64
Legal (quality standard)	Standard of Finish	0.87	1.74	2.62	3.49	4.36
	Fire protection and Disability Access	0.93	1.86	2.79	3.72	4.65
	Occupational Health, Indoor Environmental Quality (IEQ), Safety and Secutrity	0.85	1.71	2.56	3.42	4.26
Political (context)	Ecological Footprint and Conservation	0.81	1.62	2.43	3.24	4.05
	Community support and Ownership	0.87	1.74	2.61	3.48	4.35
	Urban Master Plan and Zoning	0.88	1.76	2.63	3.51	4.39

Table 3.8-2 AdaptSTAR parameters weights (Source: www.adaptstarinc.com).

The star rating scheme (Table 3.8-3) shows the AdaptSTAR scores in an understandable tab. High AdaptSTAR values mean that the existing characteristics of the case study analysed can host new functions and the hypothesised adaptive reuse scenario is efficient to develop smart and sustainable urban regeneration policies.

AdaptSTAR score	*Star rating*
85 - 100	***** (5 stars)
70 - 84	**** (4 stars)
55 - 69	*** (3 stars)
40 - 54	** (2 stars)
25 – 39	* (1 star)
Less than 25	Unranked

Table 3.8-3 AdaptSTAR Model star rating (Conejos et al., 2015).

4. IMPLEMENTATION OF MULTI-CRITERIA DECISION-MAKING ANALYSES (MCDMA) ON ABANDONED INDUSTRIAL SITES IN BARI

4.1 An overview of dismissed industrial areas in Bari

The development of the industrial and production sector in the city of Bari dates back to 1836, when Guglielmo Lindemann built the first metalworking factory in the Apulian capital. In the subsequent years, new industrial settlements, gasometers, oil mills and cotton factories began to take away spaces from the natural environment surrounding the city of Bari and occupy the areas outside the existing urban conglomerate. From the second half of the nineteenth century, the urban fabric of the Murat district was interrupted by the construction of department stores that highlighted the physical limit of the city until then built. In particular, the area adjacent to the Murat chessboard and the places close to the Estramurale Capruzzi were characterized by industrial densification activities, creating new industrial peripheries. The latter, due to lack of space in the existing city asset and for reasons of environmental opportunity and spatial availability, developed processes of extra-moenia expansion, with the subsequent creation of the first urban suburbs (Opificio del Gaz, 1865; Saponerie Meridionali, 1868; Falegnameria Sallustio, 1985; Oleificio Ligure Pugliese “Gaslini”, 1895; Nuovi Magazzini Generali “E. Fizzarotti”, 1895). One of the determining factors of the promotion and expansion of the secondary sector in the city of Bari is attributable to the willingness of many foreign and local entrepreneurs to invest in this strategic context, strengthening sea and rail links with the aim of upgrading the supply and

provision of raw materials for industry, as well as reducing production times and introducing new efficient products in the market.
The advent of the two world wars didn't stop the industrial development process of the city of Bari. At the same time, new large and extensive steel, electrical and commercial plants began to spread like wildfire in the west part of the Apulian capital and, more specifically, in the Peninsula of San Cataldo (New General Markets, 1930; Apulian Steelworks and Foundries "G. Scianatico", 1932) and in proximity of the Lama Lamasinata (STANIC Refinery, 1938), constituting working-class neighbourhoods. Over the years, the strong and disruptive urban expansion that characterized the sixties and seventies of the Apulian chief town and the drafting of new regulatory plans has totally changed the morphological and infrastructural scenario of the city, eliminating many of the historical industries of the late nineteenth century and dislocating new productive and commercial volumes in the marginal suburbs of Bari beyond the main perimetral roads (ASI Bari-Modugno Consortium, 1960). In addition, the twentieth century crisis in the secondary production sector had fostered processes of divestment of many of the remaining industrial archaeology sites and of a large quantity of activities located in the ASI Consortium, disintegrating the existing urban fabrics and forming isolated district entities without community services. A recent census of abandoned and dismissed contexts in the metropolitan area of Bari reveals a high presence of unused production areas (4.769.523 sqm) equal to 62.5% of the total disused surface (7.610.064 sqm), not considering the sheds previously occupied by former military sites or the infrastructure wrecks (Calace et al., 2013).

Nowadays, the city of Bari is composed by three wide industrial areas with a high number of disused warehouses (Figure 4.1-1):

a) The first area contains the remains of industrial archaeology realised in the period before World War II. Incorporated into the mixed residential building fabrics that occupy the San Cataldo district and limited to the east by the Libertà district and to the west by the complexes of the Fiera del Levante, the Arena della Vittoria and the Municipal Pools, the former Gaslini oil mill and the

Scianatico steelworks represent two of the few remaining examples of historic industrial heritage architecture in Bari. The two industrial factories, abandoned for almost thirty years until now, incorporate high conditions of context degradation and structural decay, although some of the constructions are subject to architectural preservation, since valuable elements characterizing the evolution of the production and industrial sector in the Apulian capital. In addition, their considerable extension creates a barrier between adjoining neighbourhoods, not connecting them physically and socially. However, within this mainly abandoned and dismissed historical production context, the area of the New General Markets and the former Slaughterhouse are two examples still active in the contemporary city context and respectively the first maintains its connotation of a selling place of fruit and vegetables, the second is reused, transforming the former factory into the new citadel of culture (State Archive and Sagarriga Visconti National Library);

b) A little further south, in the STANIC district, the homonymous refinery and the ENEL power plant constitute the second totally abandoned industrial area of the city. The area of about 650.000 square meters has recently undergone reclamation interventions as it is highly polluted by the waste materials of industrial production. In recent years, the two former productive sites have been the subject of studies and design urban regeneration competitions, but, at present, the projects remain only future scenarios of sustainable development without any real work progress;

c) The last production area of the metropolitan city of Bari consists of all the warehouses and companies that, since the sixties, occupy the ASI Consortium of Bari/Modugno lots. The current industrial area of Bari, much larger and denser of production and co-working facilities, includes all companies and steel, metallurgical and technological incubators still active in the territory. At the same time, in this vast productive part of the metropolitan city there is no shortage of urban voids, unfinished sheds and entire abandoned industrial sites, never reactivated or re-utilised over the years.

Interventions of refurbishment, transformation, redevelopment and urban regeneration of these abandoned sites can be undertaken through a careful study of the physical, spatial, morphological and architectural potential of each unit and the neighbouring context, as well as the local sociocultural aspects of the surrounding popular districts. This section is divided into four parts: i) analysis of the main urban planning tools, municipal and regional in force decrees regarding the guidelines to respect for the recovery and enhancement of disused industrial contexts; ii) acquisition of quantitative and qualitative data, definition of the intervention strategies that can be adopted in the ASI Consortium of Bari/Modugno and formulation of thematic data sheets for the study of morpho-typological, architectural, spatial, environmental and functional components characterizing the productive and commercial district; iii) implementation of DSSs for the evaluation of adaptive reuse interventions on disused historical and contemporary warehouses of the ASI Consortium and iv) on historic industrial heritage sites located in the adjacent STANIC district.

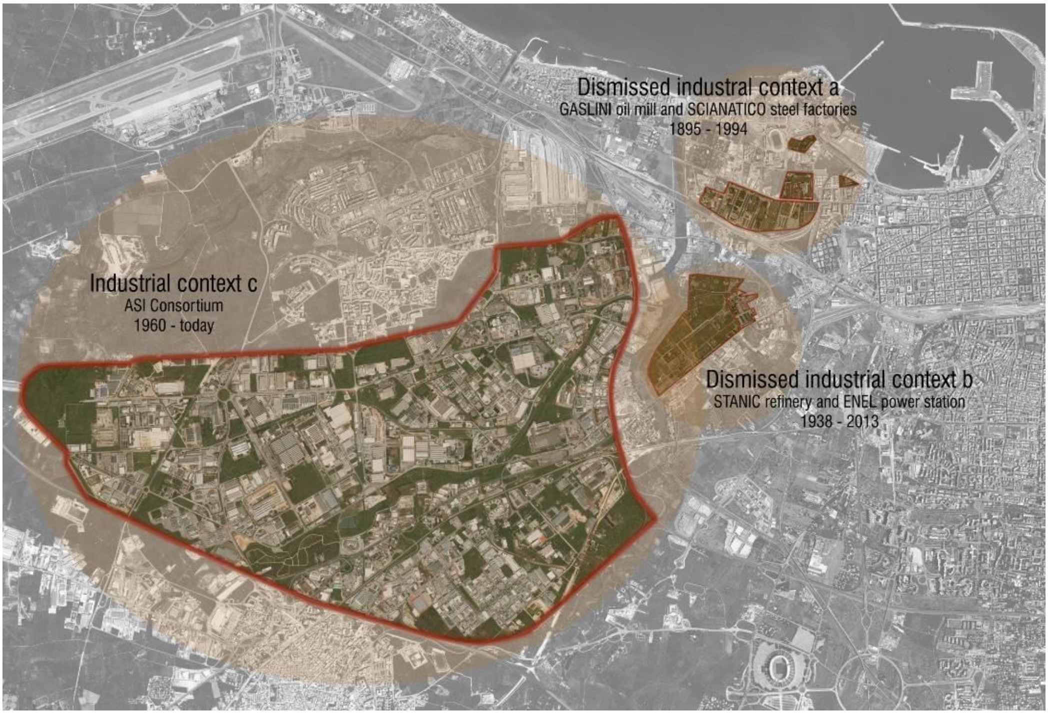


Figure 4.1-1 Main industrial dismissed and active industrial sites in Bari.

4.2 National and Regional laws on preservation and valorisation of derelict industrial contexts and urban planning tools

The definition of the state of disposal of an industrial site and the connotation of an abandoned warehouse includes a series of units and structures used in the past for manufacturing and production activities and which are no longer in operation today. This great existing resource if not enhanced with processes of functional reuse, environmental protection and refurbishment of the architectural, construction and shape values of industrial heritage archaeology buildings can damage the city system, making the transformed envelope not compliant to the contemporary demands and needs of society.

The regulatory framework concerning the theme of disused industrial areas is dealt with, according to the national sphere, in two legislative topics that identify the reclamation of polluted territories and urban planning of the territory. These rules promote the conversion of decommissioned factories, considered as fundamental thematic fields for implementing future feasible and efficient interventions on the existing heritage. In particular, Article 252 of Legislative Decree No. 152/2006 (Decreto Legislativo n. 152, 2006) lists the principles and guiding criteria for the identification of places of national interest subjected to reclamation actions, considering the intrinsic characteristics of the site, the quantities and danger of pollutants factors, the incidence of the impact on the surrounding environment in terms of health and ecological risk, as well as damage to cultural and historic heritage. The Legislative Decree No. 4 of 2008 (Decreto Legislativo n. 4, 2008) has supplemented the previous document by including in Article 252a , "sites of preeminent interest for industrial conversion", the actions to be carried out for the identification of industrial areas affected by conditions of high physical degradation, pollution and abandonment, for the definition of safety and reclamation activities on dismissed industrial contexts and for the design of innovative and economically punishable conversion methods.

From an urbanistic point of view, the reference law to encourage the rationalization of the existing building stock and the promotion, facilitation and redevelopment of degraded urban areas is the Decreto Sviluppo No. 70 of 13 May 2011 (Decreto-Legge n. 70, 2011). This document introduces all the incentives for maximum additional volumes, their relocation, changes of destination uses and interventions for modifying structures envelope and shape.

With regard to the measures that provide the conversion and redevelopment of derelict industrial warehouses, the Bill No. 1836 of 2015 (Disegno di Legge n. 1836, 2015) proposes interventions to recover these unused places as a consequence of the serious contemporary economic crisis. The text of the draft legislation indicates that industrial areas at risk of crisis and divestment are located throughout the national territory with a situation of greatest criticality in the South Regions of Italy. More specifically, the document focuses the aspects of conversion and redevelopment of disused industrial construction, reintegrating these real resources within innovative and sustainable city development programmes, creating public spaces for the community and increasing local job opportunities.

An important role for the management and protection of the territory is assumed by the regions. These administrative entities provide to formulate planning tools and guidelines for the reclamation and redevelopment of polluted and disused industrial plants. In particular, the Puglia Region, through the Regional Law No. 17 of 30/11/2000 (Legge Regionale n.17, 2000), defines functions and tasks in terms of environmental protection and the reclamation of polluted territories. The contents of this law face up the themes of preservation, safety and landscape refurbishment of contexts with a high risk of soil, water, air, electromagnetic and acoustic pollution, as well as explain the environmental impact assessments, waste management actions, territorial safeguarding procedures and hydro-geological resources monitoring activities.

The topic of the abandoned industrial heritage enhancement is also treated in regional statements. The Puglia Region, in fact, is one of the first Italian territories to emanate a regulatory tool that affirms the importance of historical production contexts, promoting activities for the recovery of the existing abandoned sheds and connecting the Apulian industrial past with the technological and virtual present of smart cities.

The Regional Law No. 1 of 27 January 2015 (Legge Regionale n.1, 2015) defines the industrial archaeology as the complex of intangible and material assets, no longer used for the production process, which constitute historical testimony of the work and industrial culture present in the regional territory. Moreover, the document lists the activities of valorisation of the industrial heritage that include not only census, safeguarding, recovery and conversion of warehouses of historical interest, but also dissemination and cultural processes of knowledge through educational workshops and touristic didactic itineraries.

In addition, the Puglia Region considers the directives dictated by the European Development Strategy "Europa 2020" (Europa 2020, 2010) summarised in three main points:

1) Smart growth: developing a knowledge-based economy, innovation, education and digital training;
2) Sustainable growth: promoting green strategies that are effective in terms of renewable resources, reuse of building components and materials, reducing climate impacts and CO_2 emissions;
3) Inclusive growth: providing the creation of new jobs that promote social and territorial cohesion, a higher quality of life in the city's suburbs and spaces easily accessible and usable to all people.

This general framework, therefore, projects the Puglia Region towards the implementation of processes of strengthening and transforming the existing production apparatus, the insertion of new business incubators and services for the community and the attraction of substantial financial investments in order to activate effective functional regeneration policies to improve liveability issues and social inclusion.
The Apulian scenario includes urban planning tools that interpret the critical issues of industrial dismission, offering guidelines and thematic accurate and detailed maps for the design, refurbishment and regeneration of landscaped and ecologically equipped surfaces. The PPTR (Piano Paesaggistico Territoriale Regionale, 2015) addresses the

problem of abandoned production facilities in the Apulian territory with the aim of reducing these problematic items by producing intuitive guidelines for the implementation of APPEA (Aree Produttive Paesaggisticamente ed Ecologicamente Attrezzabili) that provide: i) the redevelopment and urban re-functionalization of disused productive tissues; ii) urban stitching of industrial abandoned voids with the main territorial and architectural structures; iii) the enhancement and connection of agricultural territories with the production facilities considered for adaptive reuse conversions; iv) the redesign of the infrastructure and public spaces that form the backbone of the production district; v) multifunctional integration between different functions and services typologies (commercial, offices, cultural, educational, etc.); vi) the raising of the aesthetic and compositional interventions quality that involve the technological and architectural elements of industrial reuse design solutions and vii) the promotion of functional programs that encourage the use of industrial suburbs throughout the day.

The classification of environmental issues and risks merged in the Bari metropolitan context is implemented in the descriptive tables of the DPP (Documento Programmatico Preliminare). Drafted as a preparatory act to the process of formation of the General Urban Plan (PUG) according to the Regional Law no. 20 of July 27, 2001 (Legge Regionale n. 20, 2001) and the Regional Document of General Planning (DRAG) approved with the Deliberation of Regional Council n. 1328 of August 3, 2007 (Deliberazione Giunta Regionale, 2007), the DPP provides detailed conceptual and thematic maps about the urban, environmental, functional and morphological dispositions on the metropolitan territory of Bari, as well as graphic data sheets defining perimetries of hydrogeological and flooding risks places according to the Basin Plans. These downloadable and intuitive posters represents fundamental documents for the formulation of effective adaptive reuse strategic scenarios in each peripheral context of Bari, as it provides reliable data on the components characterizing marginal and abandoned industrial urban fabrics and social hierarchies and needs of the surrounding neighbourhoods.

4.3 Data acquisition on ASI Consortium of Bari/Modugno

Before proceeding to the definition of sustainable scenarios and to the application of decision support models for the selection of the most effective and suitable adaptive reuse approach for each ASI Consortium of Bari/Modugno case study, this section provides to list the analysis sheets extracted from the monitoring and on-site activities and by cartographies and thematic maps of DPP. In addition, a third part explains the achievable planning strategies applied on Bari industrial area for dismissed warehouses adaptation, sustainable regeneration and functional conversion of spaces.

In particular, the three paragraphs that constitute this part of research can be schematised as follows:

a) General overview of the evolutionary phases concerning the expansion of the ASI Consortium in the city periphery and synthesis of the data obtained from the on-site reconnaissance activities, mapping through QGIS platform and elaboration of conceptual tables through graphics software (Photoshop, AutoCad) about the shed, environmental and infrastructure main components englobed in the industrial context;
b) Differentiation of warehouses construction typologies according to their year of construction;
c) Identification of project guidelines for the development of innovative policies for the transformation of dismissed production areas in compliance with landscape features, environmental constraints and urban infrastructures already rooted in the territory, reducing land consumption, improving energy efficiency and saving, technological design solutions, passive surveillance and spaces accessibility, and promoting integrated and participatory planning workshops and design sustainable and iconic architectures to amplify social attractiveness and curiosity.

All these information and analysis tables allow to display accurate and interesting features regarding the ASI Consortium morphology. In addition, these schemes serve to preliminary recognise case studies main components for the conception of plausible reuse and regeneration scenarios and subsequent ranking of alternative with decision-making evaluation tools.

4.3.1 Site stats and analyses

In order to define adaptive reuse strategies and functional, architectural and technological solutions to hypothesize for the transformation of the ASI Consortium of Bari/Modugno disused industrial warehouses, it is necessary to outline a general focusing on the evolution and the actual conditions of this marginal and vast site.

The industrial area of Bari was established in 1960 when the rapid increase of industrial investments favourited the creation of new companies in the provincial territory. The need to structure and design a unitary industrial apparatus that could enclose multiple factories and production activities implies analyses and stakeholders' interactions, understanding the viable scenarios to perceive this objective. In particular, the convention for the establishment of the Consortium for the Industrial Area of Bari-Modugno was signed on February 13, 1960 between the Administration of the Province of Bari, the Municipality of Bari and the Chamber of Commerce, Industry and Agriculture of Bari. This wide industrial agglomeration is developed to encourage new initiatives and investments in the productive, commercial and manufacturing sectors in the context of the city of Bari. The ASI Consortium of Bari/Modugno occupies an area of about 1500 hectares, located close to one of the most populated and decentralized residential districts of the city, the San Paolo district.

The industrial area of Bari/Modugno is also lapped by the major fast-track roads and its barycentric position within the metropolitan area has facilitated over the years the introduction of an increasing number of companies and incubators. Nowadays, the ASI Consortium is largely served by urban infrastructures and contains 60 business incubators.

The ASI Bari/Modugno Consortium includes precise Technical Standards regulations (NTA) concerning the Executive Urban Plan of the Industrial Agglomeration of Bari-Modugno (Norme Tecniche di Attuazione, 2007). Considering the legislative body of the NTA, the production area of Bari/Modugno englobes urban and building transformations procedures through the granting of permits and acceptances (art. 3). Article 8, on the other hand, contains all the requirements that determine the size of the fences, the type and number of plantings and green areas, the relationship with infrastructures, the insertion of services and parking areas, as well as the distances to be respected between the buildings and lots boundaries. Finally, the NTA provides to define refurbishment and strategic re-functionalization policies of disused sheds, preserving the identity and architectural features iconic of productive fabrics as a cultural testimony in the field of industrial building tradition and actively relocating these resources in the contemporary city structure with the creation of job opportunities and attractive poles in relation to APPEA key point and objectives (art.11).
However, to better frame the peculiarities and problems of the ASI Consortium of Bari/Modugno, data, obtained from the in situ inspection, monitoring and mapping activities and from in-depth studies of the documents related to its historical evolution and DPP cartographies, are summarized in eight thematic tables distinguishable in three different main issues: i) environmental; ii) infrastructure and iii) spatial.
The different conceptual maps are formulated using the rasterized and editable files of the polygons, lines and points (ctr_pol; ctr_lin and ctr_poi) of the ASI Consortium area available in the download section of the Sit Puglia website (www.sit.puglia.it). The same are uploaded in the QGIS platform to proceed with the surface mapping phases. In addition, to give a greater graphical rendering to each table, the files exported from QGIS are modified and adjusted with the use of modelling and photo editing programs (i.e. AutoCad and Photoshop).

The first thematic field studied concerns the characterization of the environmental planning of the territory of the ASI Consortium and the surrounding natural landscapes.

In particular, the two maps extrapolated from the analyses and monitoring phases identify respectively:

1) The system of urban, agricultural and uncultivated green areas presents within the industrial area of Bari/Modugno and in its proximity. Figure 4.3.1-1 (Figure 4.3.1-1) illustrates the punctual disposition within the ASI Consortium of numerous unused areas to transform in urban greenery. Many of these areas are included in the lots of some decommissioned industrial warehouses or represent empty spaces not yet occupied by productive activities. The perimetral contexts closely related to the case study have mostly agricultural connotations due to the high presence of cultivated fields and olive groves and orchards;
2) The hydrogeological asset and the soil lithology, considering the information contained in the maps of the Hydrogeological Plan of the Puglia Region available from the site of the Municipality of Bari (www.comune.bari.it). This second environmental thematic map identifies the surfaces subjected to the risks of flooding and water dispersions (Figure 3.4.1-2). In particular, the area of the ASI Consortium is cut transversely by the Lama Lamasinata and lapped to the northwest side by Lama Balice. These karst formations convey the rainwater to the sea and, therefore, present a high flooding and accumulation of rainwater hazards. From this second framework it is possible to deduce how the reuse and conversion planning activities of disused industrial warehouses bordering Lama Lamasinata and Lama Balice must take into account the hydrogeological risk and provide strategic solutions for rainwater disposal and containment of flows in the copious flooding events. The lithological characteristics of the substrate are mostly attributed to limestone or evaporative rocks.

The two illustrative maps concerning the infrastructure system (Figure 3.4.1-3) and functions (Figure 3.4.1-4) introduced in the industrial area are fundamental for the formulation of effective functional renewal policies to develop well-defined and ecologically equipped production structures. More specifically, the documents illustrate respectively:

A) The hierarchy of road links by dividing driveways into highways, suburban roads, urban roads and local streets. Looking more in detail at the infrastructure skeleton within the ASI Consortium of Bari/Modugno, two main sliding arteries correspond to the Cardo (Viale Francesco de Blasio) and the Decumano (Strada Provinciale 54) that cross the entire lot horizontally and vertically and connect the production area to the east with the city center and the ring road, to the south with the A14 highway and the SS96 and to the north with Bari-Palese international airport and the San Paolo district. From these, the secondary roads mark the composition of the factories and lots surfaces, allowing to reach the different companies. In addition, this third conceptual table considers the footprint areas of the rail connections and the airport site extension, as well as the disused tracks still included within the productive industrial context;
B) The services and uses included in the industrial and productive area of Bari/Modugno and in the San Paolo and Stanic districts. The functional framework that characterizes the lots of Bari/Modugno manufacturing area presents mostly companies for industrial, productive and commercial purposes. Large shopping malls and distribution centres are concentrated in the north-east part of the ASI Consortium, while educational functions and primary services for the community can be limitedly found in the northern residential district. A negative aspect that emerged from the analyses of existing functions concerns the total lack of attractive elements for cultural and tourist promotion.

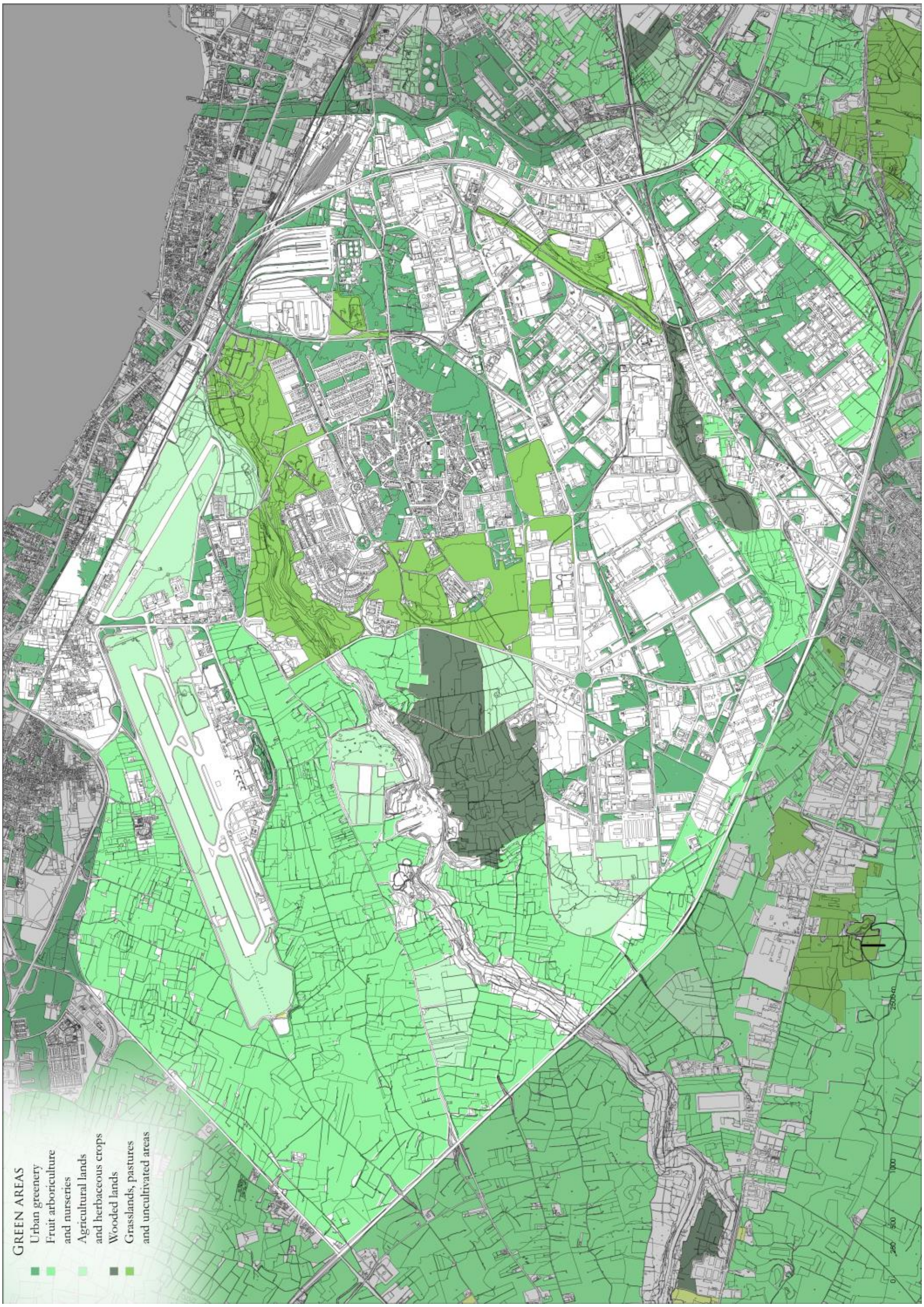


Figure 4.3.1-1 Green areas thematic map.

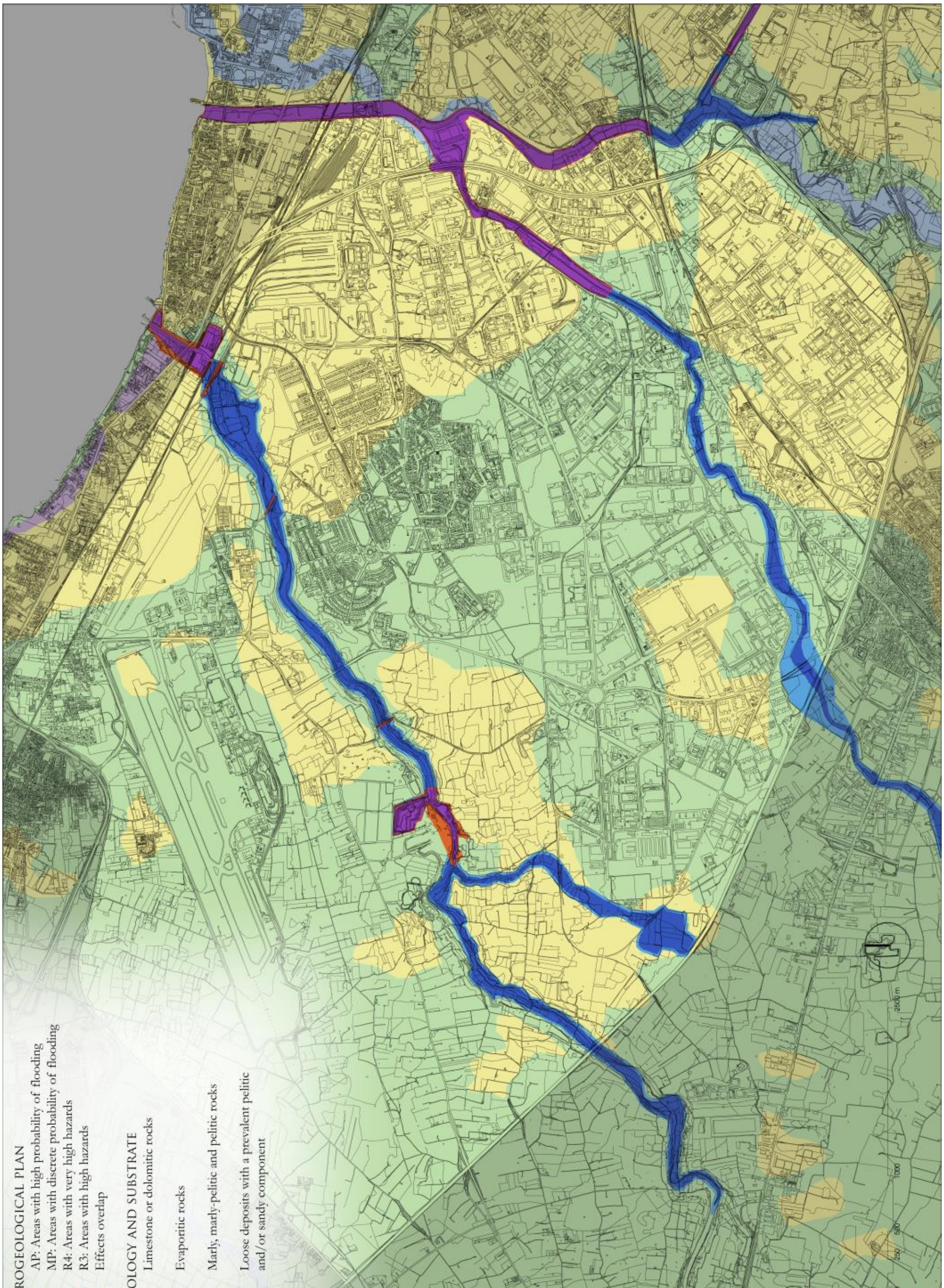


Figure 4.3.1-2 Hydrogeologic and lithology thematic map.

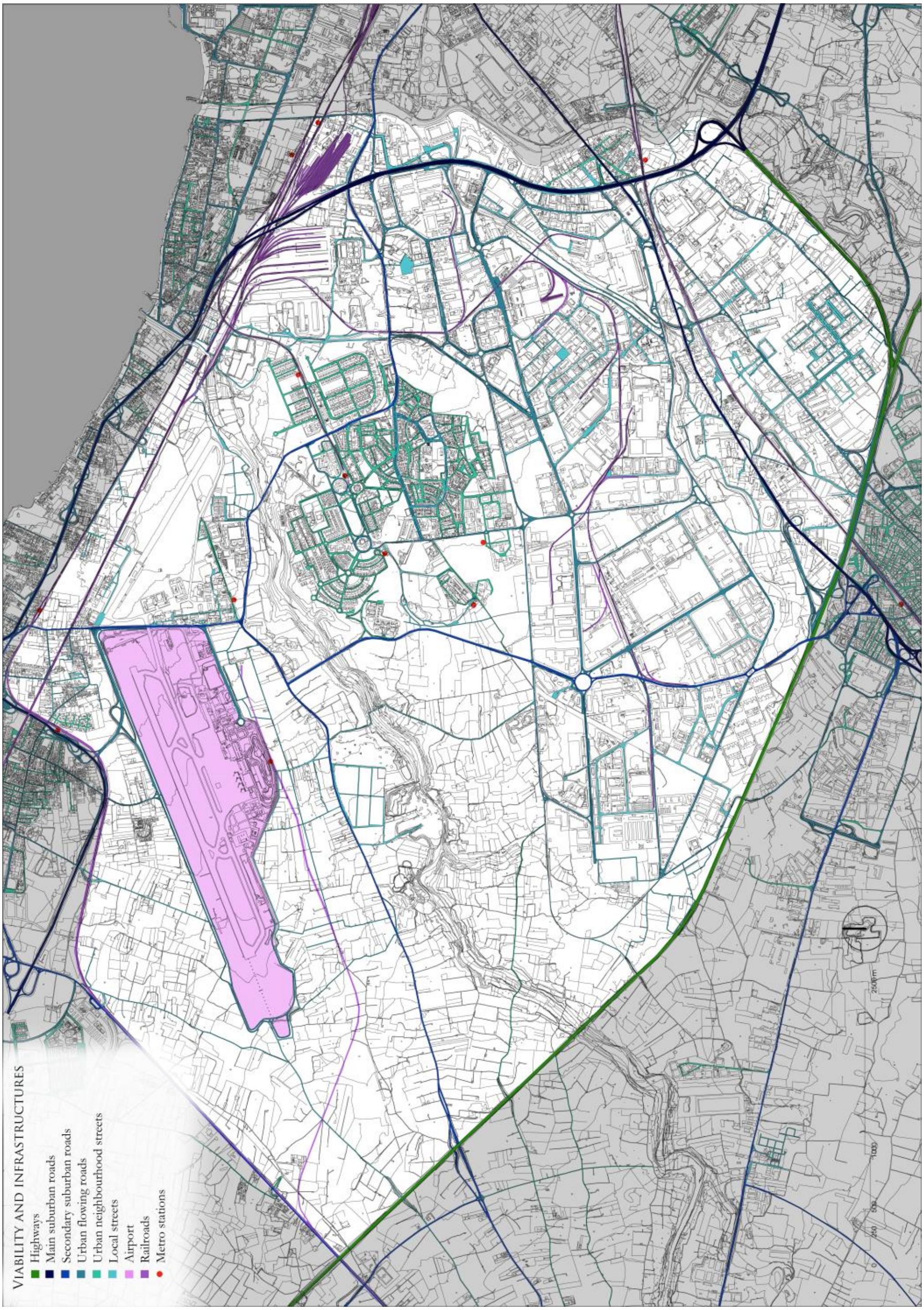


Figure 4.3.1-3 Viability and infrastructures thematic map.

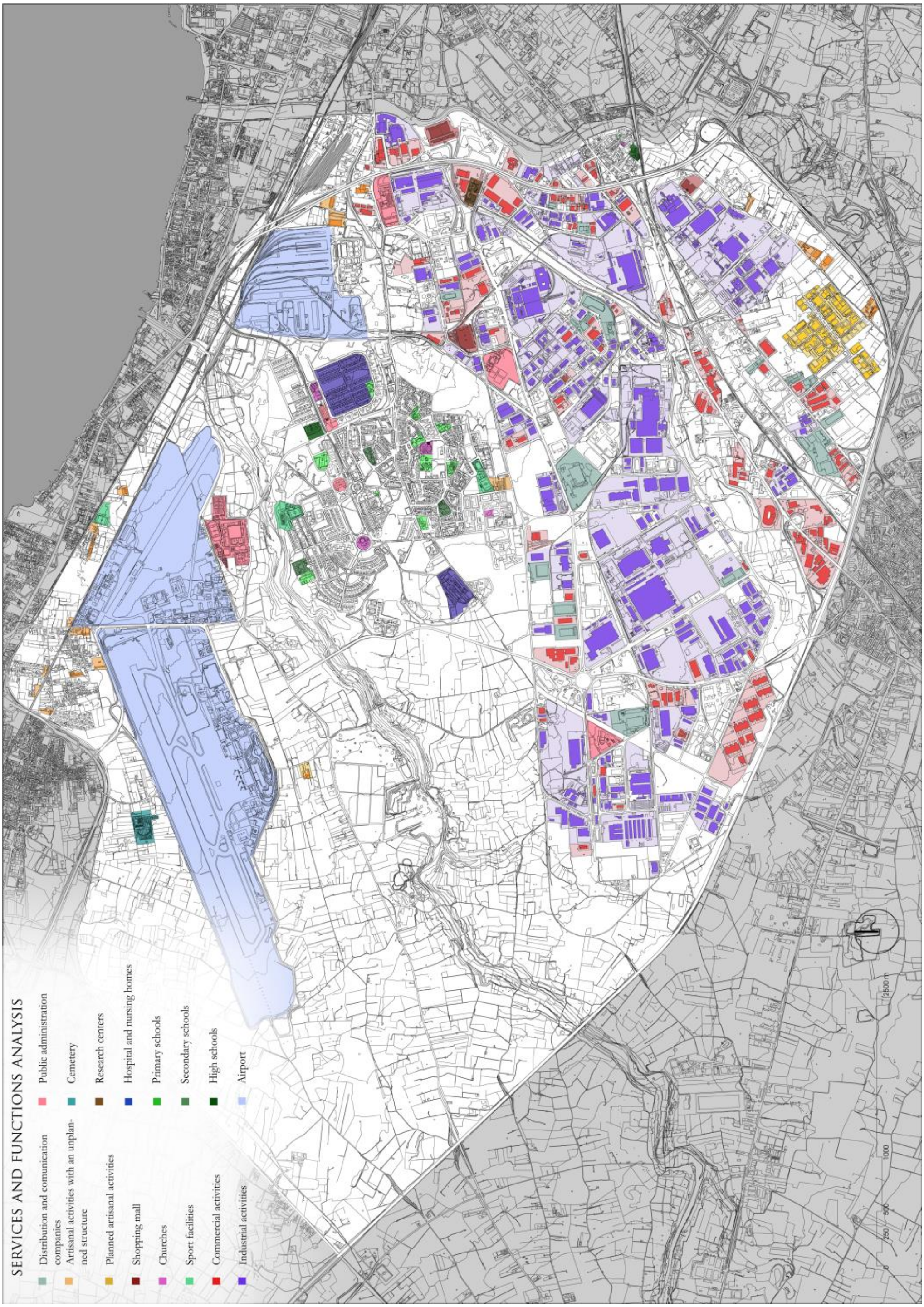


Figure 4.3.1-4 Functions and services thematic map.

The third and final topic that makes up the cognitive data framework of the intrinsic peculiarities of the Bari production area concerns the classification of the spatial components of lots through the design of four thematic maps that focus attention on buildings heights (Figure 3.4.1-5), industrial sites surfaces (Figure 3.4.1-6), differentiation between compromised and active warehouses (Figure 3.4.1-7) and the ASI Bari/Modugno Consortium historic evolution (Figure 3.4.1-8).

Going more in detail about the land surveys results contained in the four thematic maps, a series of considerations can be explained:

a) The majority of the factories included in the ASI Consortium area has heights between 5 and 15 meters except for punctual architectural singularities corresponding to chimneys or office facilities. In addition, the study also provides data regarding the maximum heights of residential buildings in the San Paolo neighbourhood. They are classified in the range between 15 and 25 meters with linear residential typologies that reach up to 35 meters in height. This information makes it clear that the neighbourhood population density is very high and, at the same time, as sustainable interventions and urban regeneration policies of abandoned industrial contexts can provide opportunities for aggregation and work opportunities to a large number of inhabitants;
b) A discrete number of lots contemplate surfaces between 35.000 and 50.000 square meters, with five cases exceeding 100.000 square meters of extension. The subdivision and scanning of factory companies help to frame the production activities influencing the morphology of the ASI Consortium, as well as an accurate definition of the perimeters of the active and disused warehouses and industrial agglomerates;
c) A large number of sheds correspond to abandoned structures, unused for years and never reactivated. In particular, for a total of 692 production lots, 19% of industrial areas (130 industrial warehouses) are disused and relinquished, while 81% (562 industrial warehouses) are still active. Turning this data into surfaces results that the abandoned built-up area fills 479.388,5

square meters, while the active industries surfaces occupy 1.920.000 square meters. The numerical data about the sqm of disused warehouses on the one hand may alarm stakeholders, showing that the economic crisis has largely affected all the commercial, manufacturing, steel and craft sectors, but, on the other hand, helps experts and developers to stimulate and invent new smart scenarios that, starting from the existing latent resources sprinkled in the urban suburbs, contribute to develop modern concepts and innovative solutions of interconnected, accessible and sustainable city;

d) The activities that have been rooted for a long time within the industrial area of Bari/Modugno correspond to the lots, described in point b, characterized by larger surfaces. Starting from these industrial sites, over the years the construction of further warehouses, mills and sheds has filled the interstitial empty spaces between the main wide plants already active. In the last thirty years, new production sites have expanded the area of the ASI Consortium westwards. Table 4.3.1-1 (Table 4.3.1-1) distinguishes the number of industrial warehouses built over decades. Although the ASI Consortium was approved in the 1960s, the analysis of the historical evolution of the site is carried out accounting the 1970s as first date when a discrete number of factories structures already occupy the Bari/Modugno industrial and productive area.

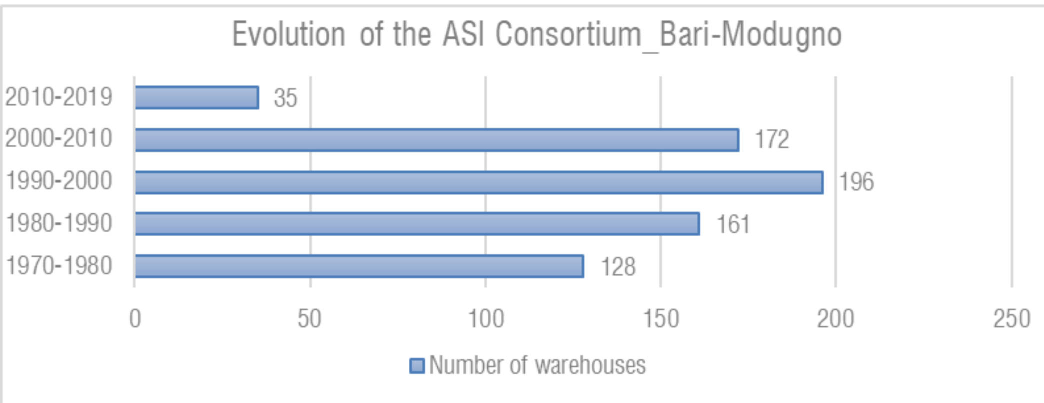


Table 4.3.1-1 Number of warehouses realised in each decade starting from 70's.

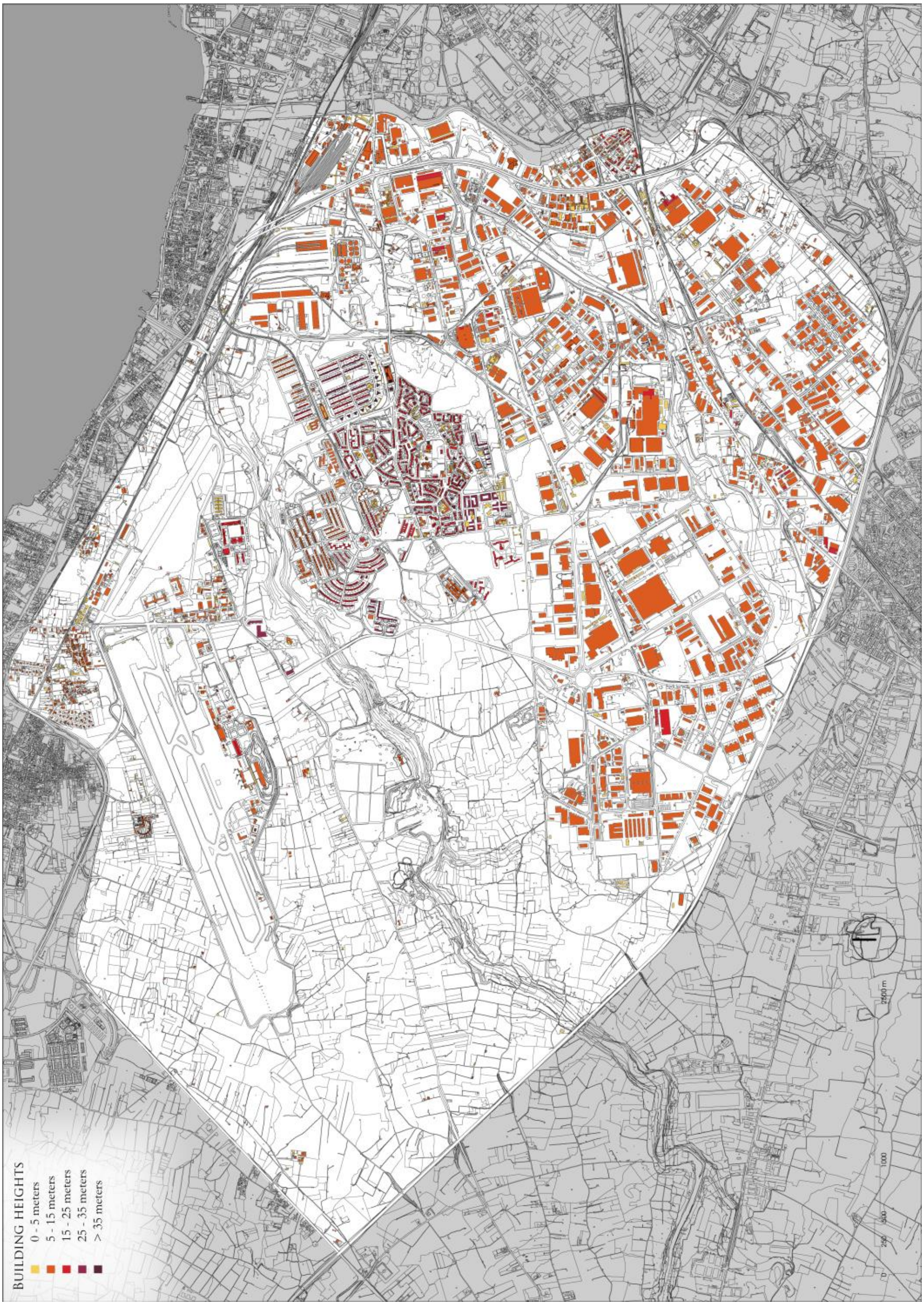


Figure 4.3.1-5 Building heights thematic map.

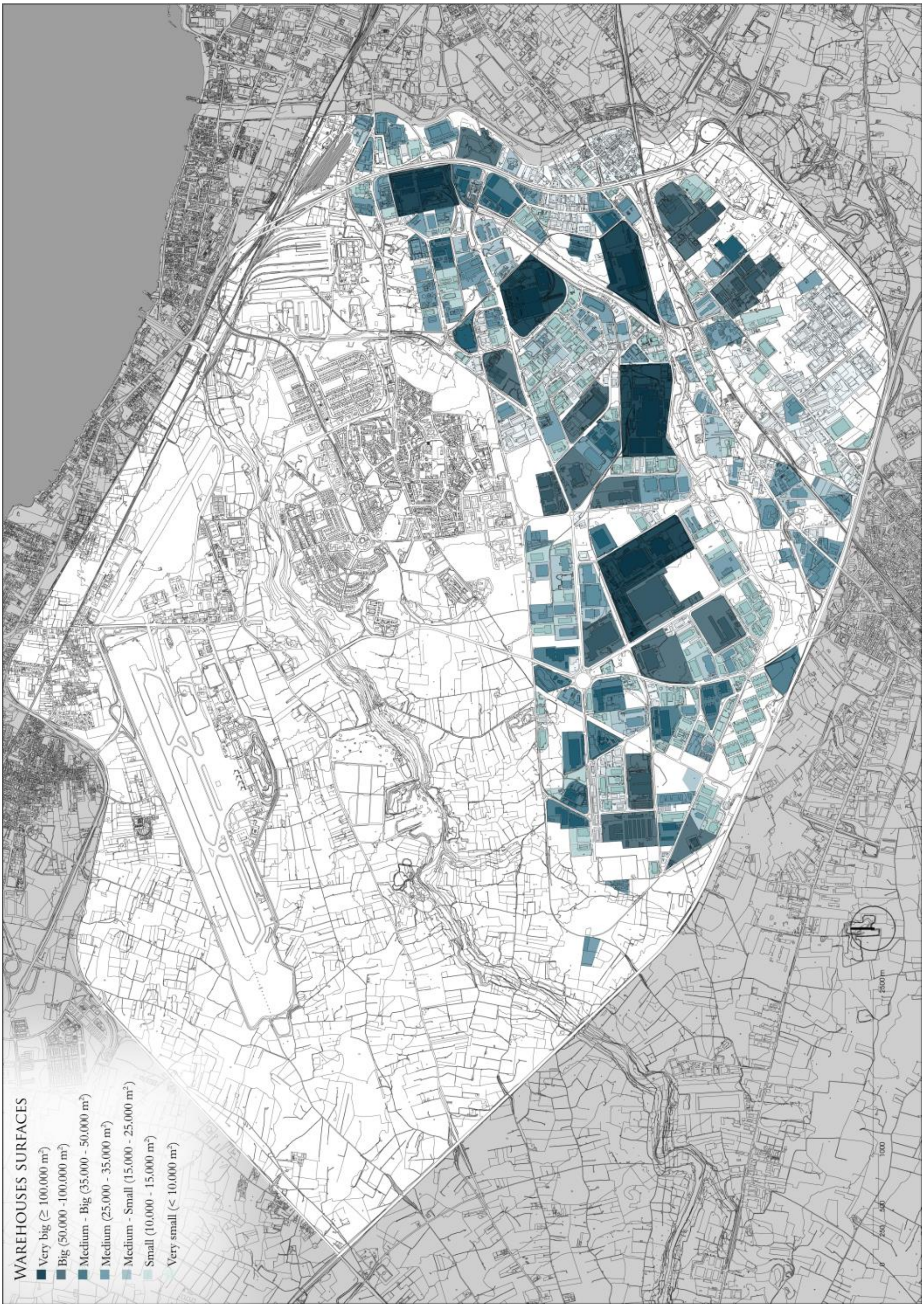


Figure 4.3.1-6 Warehouses surfaces thematic map.

Figure 4.3.1-7 Abandoned and active warehouses thematic map.

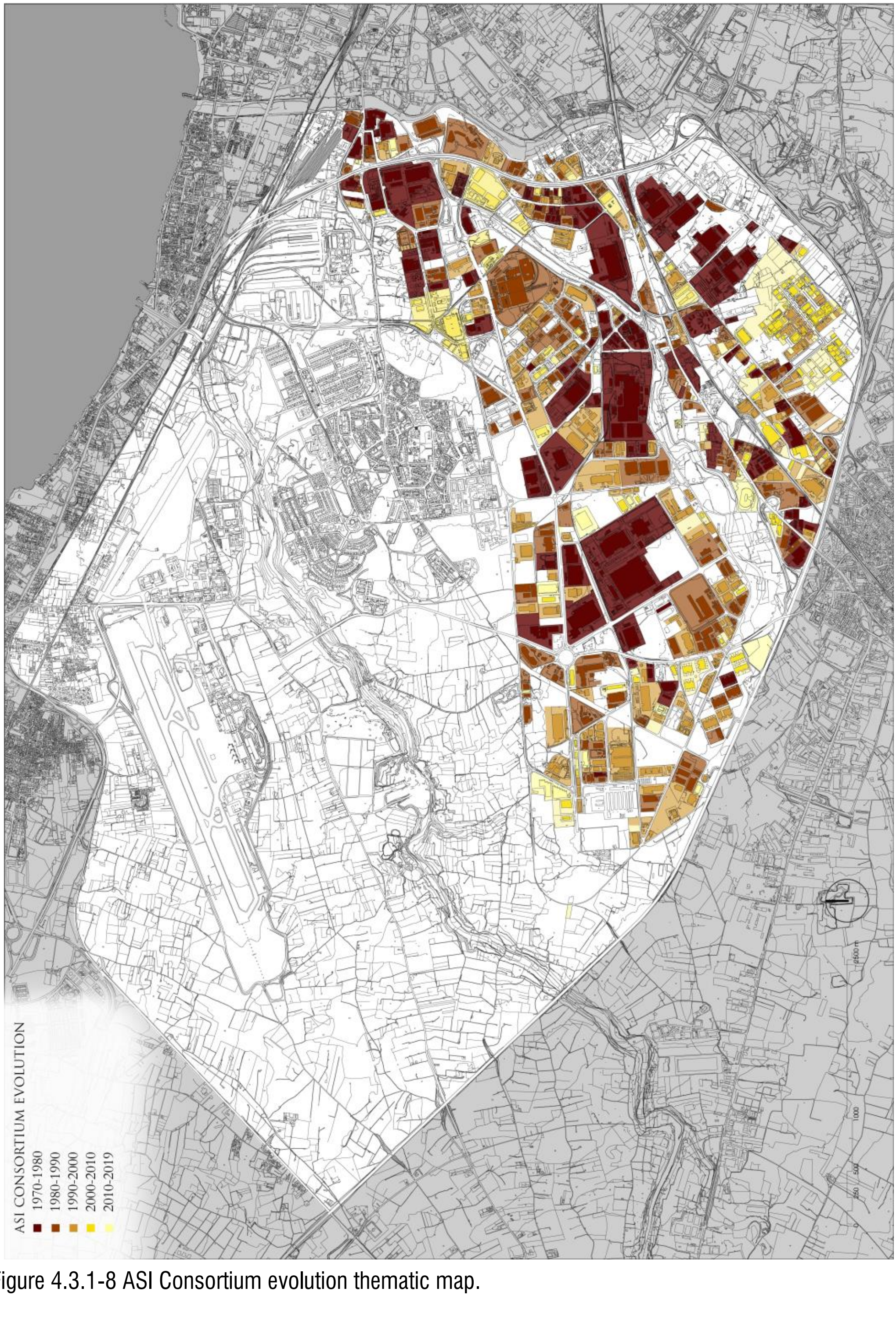


Figure 4.3.1-8 ASI Consortium evolution thematic map.

4.3.2 Building typologies classification

A ninth analysis, closely related to the thematic map about the evolution of the consortium area, provides to the classification of building structural types composing the industrial area of Bari/Modugno. The procedure is conducted through a deepening of 13 projects deposited at the ASI Consortium of Bari/Modugno headquarter.

The factories are catalogued in relation to their construction period and their structural characteristics (Figure 3.4.2-1). The five identified types are listed as follows:

a) Type A: industries, built between 1970 and 1980, characterized by structures with reinforced concrete pillars and metal truss beams; metal frame structure and volumes with shed roofs;
b) Type B: sheds, built between 1980 and 1990, characterized by prefabricated frames in prestressed reinforced concrete;
c) Type C: warehouses, built between 1990 and 2000, composed by skeletons of beams and pillars in prestressed reinforced concrete or pillars in reinforced concrete and steel truss beams;
d) Type D: factories, built between 2000 and 2010, with prefabricated structures of beams and pillars in prestressed reinforced concrete;
e) Type E: warehouses built between 2010 and 2019, composed by prefabricated structures in prestressed reinforced concrete.

This typological differentiation of factories structures has revealed a widespread and predominant use of reinforced concrete and steel elements.
However, The ASI Consortium site also contains buildings with a mixed bearing structure made by steel and reinforced concrete framework, or in reinforced concrete and bearing wall partitions. In addition, prefabricated solutions and typical shapes and elements of industrial architecture are widely adopted in the context studied, conforming building facilities with a rhythmic and easy-to-read volumes.
The conceptual map created for this study locates the different industrial activities according to their construction, compositional and structural typology (Figure 4.3.2-2).

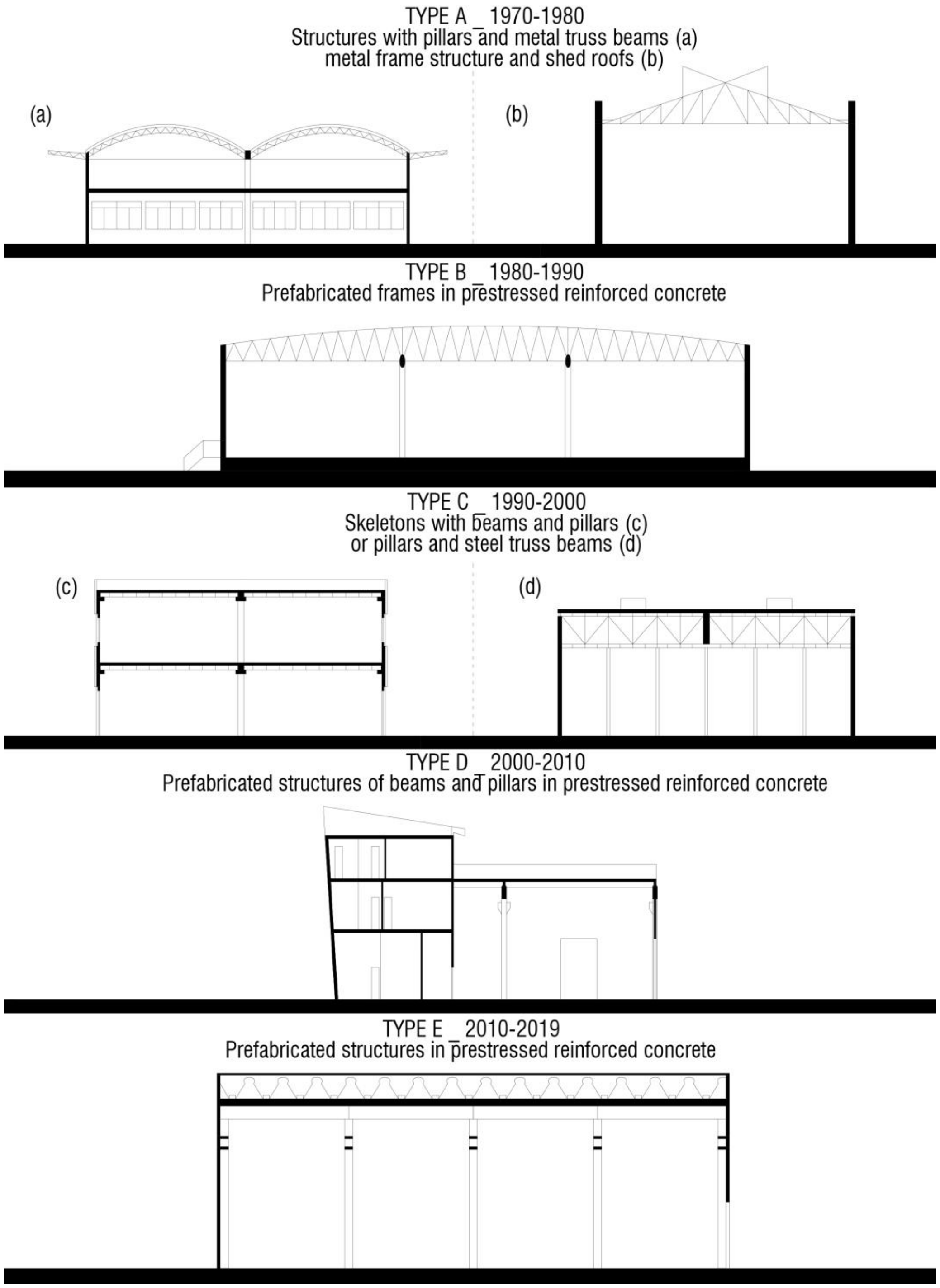


Figure 4.3.2-1 Warehouses structural typologies.

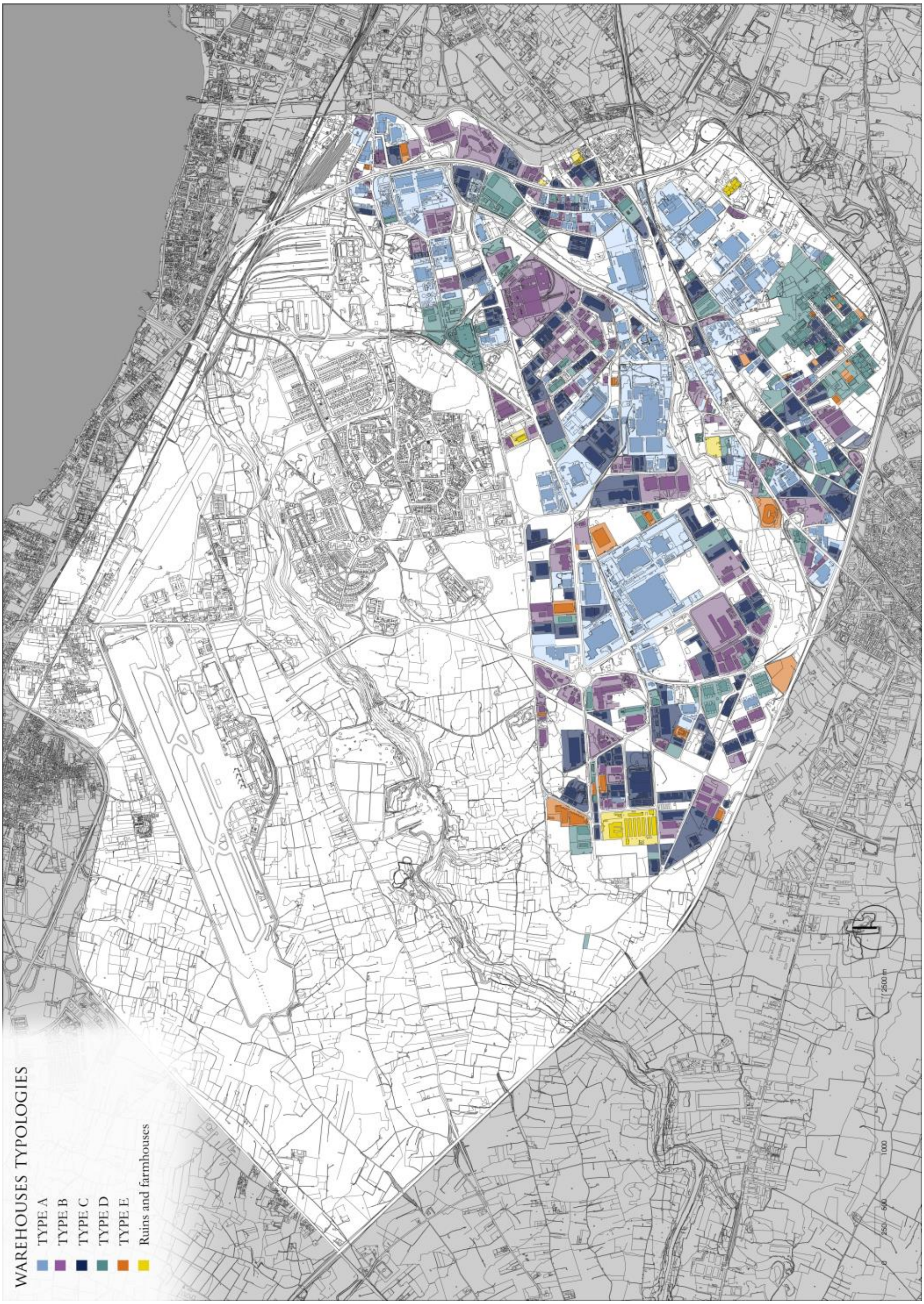


Figure 4.3.2-2 Warehouses structural typologies thematic map.

4.3.3 Strategies of intervention

All the data extracted from the monitoring, analysis and classification activities of warehouses and environmental, infrastructure and spatial components obtained by the nine thematic maps facilitate the definition of guidelines to promote redevelopment and regeneration policies of the industrial voids within the ASI Consortium of Bari/Modugno. The goal of this section consists in the individuation and definition of strategic interventions focused on developing a contemporary and futuristic dimension of the ASI Consortium as a hub and metropolitan incubator equipped with logistical, productive, cultural and infrastructural services connected with satellite companies in the province of Bari.

In particular, the framework of knowledge and actions that can be considered to foreshadow an innovative and avant-garde planning of the Bari/Modugno production area is synthesised in 18 points:

1) Increasing of parking areas to conform a well-organized urban space that can be easily used by the community and workers;
2) Inclusion in the infrastructural framework of the ASI Consortium of green areas, gardens and parks. This aspect not only affects the climatic, air quality and temperature reduction aspects, but also guarantees minimum services and public community spaces, providing to the socialization of workers, common users and local communities and associations;
3) Decreasing of waterproofed soil surfaces and subsequent extension of permeable areas to enable a better management of the water component and removal of water to the areas of Lama Lamasinata and Lama Balice, reducing the risk of flooding or ground collapses;
4) Reduction of roads and production activities noise pollution through targeted interventions aimed at the development of sustainable and electric public transports (tram, bus and hybrid car sharing), slow cycling mobility and the

adoption of sound-absorbing and insulating panels in the most compromised areas;

5) Reduction of environmental pollution through the implementation of innovative technologies that control CO_2 emissions in the air and exploit renewable resources for improving the self-efficiency and energetic performances of the recovered and transformed building envelopes;
6) Decreasing of visual pollution often caused by artificial elements extraneous from the context. Processes that eliminate or hide these unpleasant volumetric components favours the design of an anthropized landscape closely in contact with the territory and the surrounding neighbourhoods, consolidating and strengthening the urban city landmark;
7) Organization, planning and design of production-environmental regeneration policies that take into account hydrogeological and territorial criticalities, as well as the development and innovation opportunities that the reality offers;
8) Activation of participation policies and dynamic involvement of population and stakeholders in the processes of strategic executive plans assessment for the conversion, recovery and redevelopment of dismissed or highly deteriorated industrial warehouses;
9) Expansion of existing industrial areas and filling of urban voids in the ASI Bari/Modugno Consortium to shape Eco-Productive Metropolitan Parks that provide the construction of modern accelerators and business incubators in strategic and centripetal places, satisfying the renewed needs and requests of active and worldwide companies providers;
10) Establishment and introduction of new accommodation services and social, commercial, cultural and educational community equipment, as well as public gathering spaces (parks, squares, boulevards, sidewalks, cycle paths, green ways and pedestrian paths) alternative and complementary to industrial lots, aiming at ensuring a constant human presence at different times of the day;
11) Redefinition of the roles, functions and morphology of the ASI Consortium area through innovative and smart solutions that involve the rationalization of

soil consumption and non-renewable resources. This objective can be pursued through accurate analyses of the industrial building components, as well as design phases attentive to different urban scales, planovolumetric factories layout, reduction of energy and water consumption, increasing of neighbourhoods connecting infrastructures, production of renewable energy for settlements and public spaces, control of emissions, management of processing waste and reclamation actions of environmentally critical sites;

12) Implementation of Landscaped and Ecologically Equipped Productive Areas (APPEA) aimed at the territorial enhancement of existing industrial, craft, management, commercial activities and improvement of smart working solutions and innovative technologies and product prototypes, ensuring their competitiveness in the international market and guaranteeing the integration between industrial suburbs and local available human, financial and environmental resources;
13) Ideation, planning and construction of sustainable, passive and remote technological and safety systems that contribute to minimise buildings energy consumptions and to conform envelopes, facades and vertical and horizontal closures with high thermal, acoustic and shielding performances, perceiving indoor and architectural quality;
14) Reorganisation of mobility and urban infrastructure to facilitate entrepreneurial initiatives aimed at a new work-life relationship. The preliminary evaluation of in advance defined projects (Camionale) and the study of the existing road layout foreshadow the implementation of interconnected multifunctional poles of ASI Consortium with the main city infrastructures (Port, Railway, Airport), as well as with the points of greatest interest and tourist attractiveness;
15) Activation of regeneration and reuse programs of abandoned industrial complexes though refurbishment, adaptation, expansion and functional transformation of ASI Consortium unused lots, thickening the productive fabric and emphasizing social attractiveness;

16) Creation of new local job opportunities that can strengthen and develop the economy of the Bari hinterland in the agricultural, production and digital services sectors;
17) Local development of industry 4.0 that, starting from the analysis of the microeconomies and productive features of ASI Bari/Modugno Consortium, active companies and the synergies with the most advanced and far-sighted established industries, compare and report the data of national and international macroeconomic scenarios, providing to grasping the innovativeness of the processes and, subsequently, programming lines to strengthen competitiveness on the global market;
18) Construction of an appropriate regulatory apparatus of universal and understandable rules and standards capable to organise consortium's planning policies.

All these strategic guidelines are examined according to the functional, technological and morphological evaluation of planning recovery and regeneration policies on dismissed sheds. However, the 18 planning points of intervention for sustainable and urban transformation of the ASI Consortium of Bari/Modugno cannot be carried out and satisfied at the same time. It is, therefore, necessary to establish a priority of the actions to promote for developing policies for the smart and planned regeneration of the industrial periphery of Bari. In particular, the strategies for the adjustment of the marginal productive territory under study can be divided into two types of time-continuously different action. The first encompasses all the activities of urban regeneration (Points 2; 4; 13), programming (Points 7; 8; 11; 18) and functional and morphological conversion of the territory and constructions (Points 1; 10; 14) that can be adopted in the short term. They mend the rift between the city centre and the periphery, meeting the primary needs of the community and maintaining the pre-existing urban areas. The second strategic type of action incorporates cultural, social, technological and accommodation, production and road infrastructures (Points 3; 5; 6; 9; 12; 15; 17) to encourage the all-round use of the marginal latent spaces of the Apulian metropolis, giving a new face to fringe urban contexts and ensuring multiple job opportunities (Point 16). In addition, the strategic lines of development of the ASI Consortium of Bari/Modugno, listed above, provide a detailed picture of the future structure of the Bari industrial periphery, no longer relegated to host only productive and manufacturing activities, but to correlate natural landscape, anthropized environment to be regenerated and technological innovation. Nowadays, the area of the ASI Consortium is subjected to interventions of implementation of the local main road connections through the insertion of green roundabouts and maintenance of the driveway surface and urban furnishing components (sidewalks, road signs and lighting), already hinting at a morphological and infrastructural change and a social rapprochement projected to the connection between different neighbourhoods. This first approach to the revaluation and rehabilitation of the industrial territory represents only a first step towards a modern concept of interconnected, sustainable and inclusive city. The accurate design of the dismissed factories and the adoption of integrated policies can pursue some of the 17 SDGs of the Urban Agenda 2030 (3-Good health and well-being; 7-Affordable and clean energy; 8-Decent work and economic growth; 9-Industry, innovation and infrastructure; 11-Sustainable cities and communities; 12-Responsible consumption and production; 17-Partnerships for the goals) (United Nations Development Programme, 2015). The subsequent sections of the research rank the hypothesised design alternatives through the application of Decision Support Systems (DSSs) and estimate the feasibility of the selected adaptive reuse conversion scenario identifying input features in the DCS multi-attribute structure.

4.4 Application of MCDMA for the selection of adaptive reuse scenarios on ASI Consortium dismissed sheds

After framing the general characteristics of the ASI Consortium and the possible intervention strategies that can be implemented for the development of sustainable policies for the regeneration of the marginal Bari industrial areas through adaptive reuse models, three disused industrial sites are evaluated and analysed, aiming at the promotion of feasible regeneration and conversion actions of urban voids and providing functionally, technologically and architecturally innovative scenarios for the community. This section takes into account the methodology of Multi-Attribute Value Theory (MAVT) (Fishburn, 1967; Raiffa, 1969; Keeney & Raiffa, 1976; Ferretti et al., 2014) to classify and select the compositional or functional option that best suits the intrinsic industrial site components on the basis of judgement parameters for evaluating the proposed hypotheses and experts interviews.

In particular, the disused industrial sites considered and the objectives concerning the application of the decision support model are summarised as follows:

A) Former Manifattura Tabacchi industrial site: in this first case study the MAVT approach served for the classification of the best compositional solution to host cultural and educational functions within the ASI Consortium;
B) Former Radaelli Sud Factory: for this second scenario, the multicriteria analysis is carried out to quantify which hypothesis, considering three functional options linked to the fields of computer science, digital and augmented reality, better met the social, tourist and spatial needs of the contemporary world;
C) Former Divania site: the last dismissed industrial case study considers the application of the decision-making approach to simplify choices regarding the compositional design option that best reflected the conversion of the abandoned warehouses into laboratories and greenhouses for experimentation and cataloguing of agricultural tree essences of the Apulian territory.

4.4.1 The former Manifattura Tabacchi industrial site

The first lot of the ASI Bari/Modugno Consortium tested for the implementation and feasibility assessment of adaptive reuse transformation strategies concerns the dismissed industrial site of the Former Manifattura Tabacchi (Figures 4.4.1-1; 2). This large disused production site of about 210.000 square meters, located in the north-east part of the ASI Consortium, represents one of the first industrial plants established in the bigger manufacturing and productive area in Bari. The project of the former Manifattura Tabacchi was approved in 1961. This year coincides with the construction of the first warehouses within the ASI Consortium. The realization of the first part of the manufacturing industry ended in 1964. At the same time, over the years, additional plants and spaces were added to the already wide lot of the factory.

Figure 4.4.1-1 Former Manifattura Tabacchi industrial site location in the ASI Consortium area.

Figure 4.4.1-2 Former Manifattura Tabacchi industrial site aerial view (Source: Google Earth Pro).

In particular, the building evolution of the Former Manifattura Tabacchi factory traces three different main design time steps:

a) The first phase of the project, corresponding to the years 1961 to 1964, provides the construction of workshops, the central main warehouse devoted to the storage of goods and plant buildings located in the eastern section of the lot;
b) In the second phase (1977-78) the industrial site is enriched with other buildings which currently compose the new street front of the area. In fact, offices, the company canteen, the kindergarten and a residence for employees represent the function that occupy these new designed spaces. In addition, in these years, a further volume, on the west front, is used as a storage room and offices, increasing the site covered surface;
c) The third and final construction phase, that involves the part behind the Former Manifattura Tabacchi, corresponds with the construction, in 1984, of the raw tobacco warehouse. The building of about 15.000 square meters has a symmetrical and modular structure and two internal open space courtyards.

The area of the former Manifattura Tabacchi has been abandoned since 2006 and never reused and refurbished in the subsequent years. At present this industrial derelict site is composed of seventeen buildings of various sizes, many of which are arranged without any planimetric logic, but built to fill different needs (storage and storage) arisen when the industrial activity was still active in the territory. The factory morphologies and shapes are very regular and mostly symmetrical, consisting of reinforced concrete and steel structures, double-pitched or shed roofs and prefabricated concrete panels. Monitoring activities and periodical surveys of the abandoned site, the use of virtual and aerial maps, thanks to the help of Google Earth Pro software and satellite maps, and the design of the three-dimensional model of the existing lot with 2D and 3D graphics programs (AutoCad and ArchiCad) (Figures 4.4.1-3; 4) entails to contextualize the presence of a high level of structural degradation and a total neglect and abandonment of the sheds, as well as to understand the spatial relationships between constructions and the surrounding context. A further confirmation of the precarious condition of the site is provided by the lack of windows and fixtures on the office buildings facing the street, by the presence of important and advanced phenomena of widespread humidity and by punctual façade components collapses that involve the last realised shed in the back parts of the area.

Figure 4.4.1-3 Existing former Manifattura Tabacchi industrial site morphology.

In this section, the MAVT methodology is applied to evaluate and classify the best performing compositional choice for the conversion, through adaptive reuse techniques, of the former Manifattura Tabacchi industry. The objective of this analysis is to extrapolate the best architectural-formal option for the design of an education center that can host the Faculties of Pharmacy, Chemistry and Pharmaceutical Technology (CTF), Biotechnology and Herbal sciences and technologies and health products (STEPS) of the University of Bari. This ambitious project radically transforms the functional structure of the territory, but, at the same time, could create new job opportunities, as well as give greater attractiveness and usability of the ASI Consortium of Bari/Modugno areas.

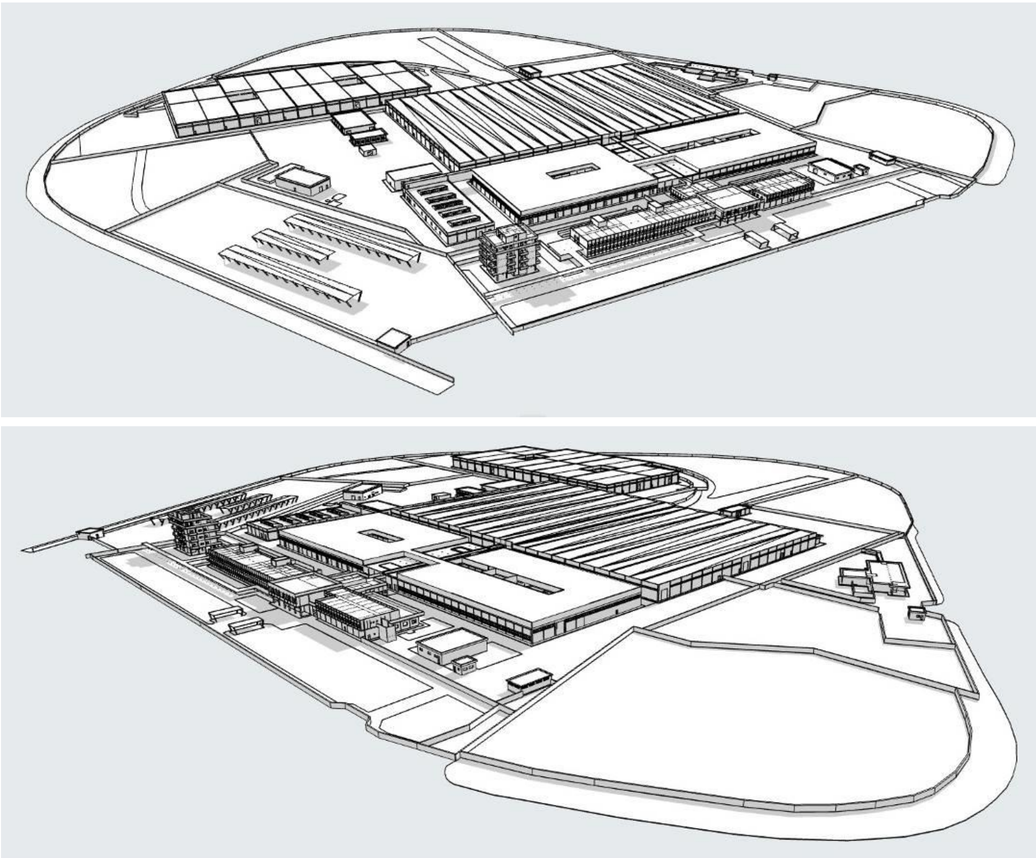


Figure 4.4.1-4 3D model interface of the existing buildings and warehouses included in the former Manifattura Tabacchi industrial site (Software: AutoCad and ArchiCad).

The functional hypothesis could also involve not only public authorities, managers and engineers who control the planning and the realization phases of industries reuse and recovery actions, but also the administrative figures of the Aldo Moro University of Bari and private and professional actors interested in investing for innovative and sustainable regeneration projects of the latent territorial resources. In addition, the

proposal focuses on the combination of places usability by students for educational purposes, experimentation and analysis of pharmaceutical products through the insertion of research laboratories and to increase the permeable soil due to the wide presence of green areas and urban surfaces, assessing community inclusion.
After identifying the peculiarities and constraints englobed in the case study and specifying the design objective of the decision-making context and the possible stakeholders involved in the factory regeneration processes, the next step consists in defining a focus group composed of expert figures in the fields of recovery, architecture, urban planning and building sustainability to select the most efficient compositional scenarios, as well as the formulation of judgement attributes and the relative value functions. In particular, for this case study, 12 professionals take part in the activity of comparison and identification of architectural options and evaluation criteria.
The debate revealed three different compositional options, and eight evaluation parameters (greenery, spaces accessibility, safety, spaces liveability, architectural quality, economic feasibility, built volumes and job opportunity).
The three design scenarios include both architectural solutions aimed at preserving and enhancing the existing dismissed fabric, introducing green spaces and squares, as well as new construction interventions that lead to increase volumes density (Figure 4.4.1-5). More specifically, all the proposed alternatives provide a first dismantling of superfetations and covers significantly damaged over the years and no longer effective to satisfy the parameters of interior design quality and indoor spaces comfort (in red).

At the same time, the hypothesised architectural strategies contribute to design interesting connections between buildings that play on the introduction of new formal aspects to boost up the opportunities of implementing smart adaptive reuse interventions:

1) The first compositional choice introduces new volumes and surfaces identified by the two towers, the envelope located symmetrically with respect to the existing office building, two buildings of considerable extension on the right

side of the central shed and the connection, though catwalks, of the monumental front with the pre-existing warehouses in the middle of the industrial site.

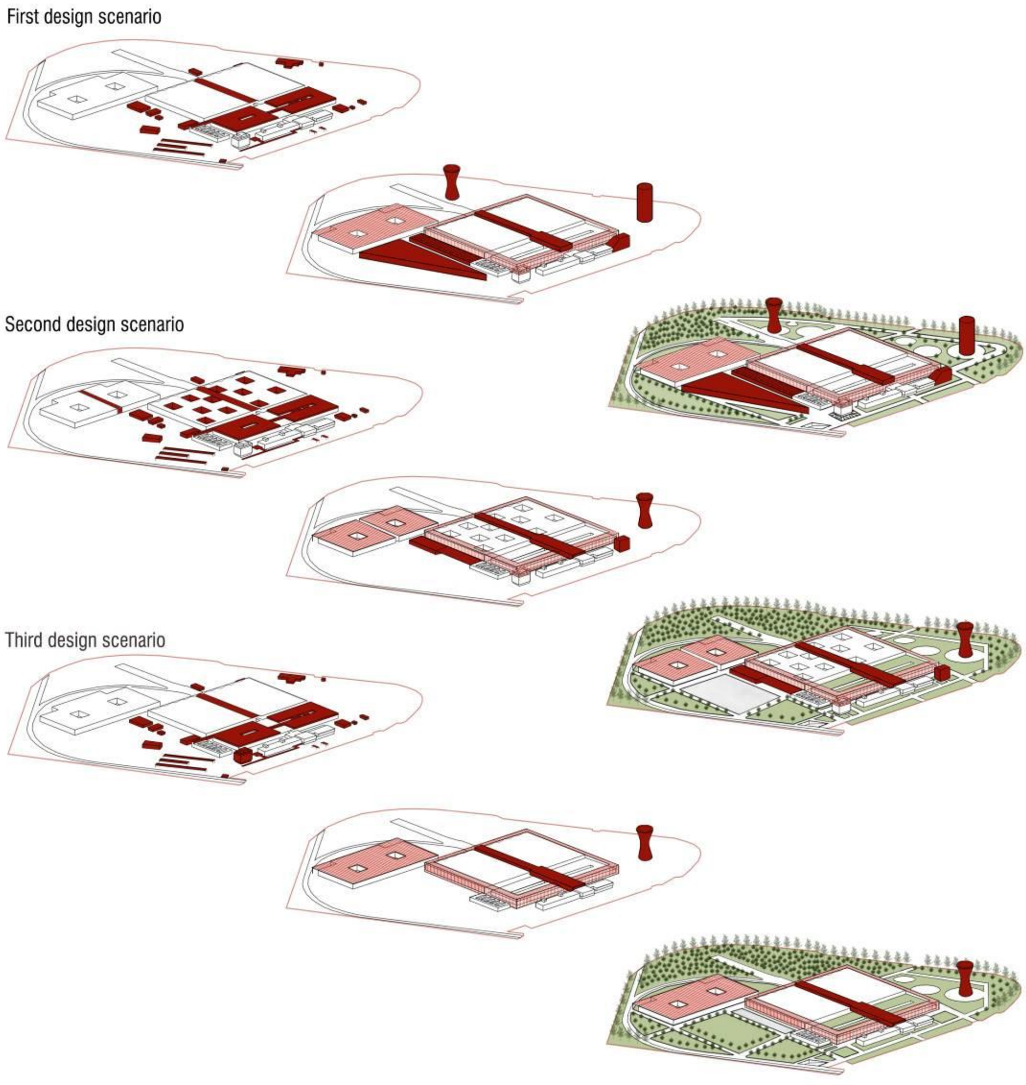


Figure 4.4.1-5 Former Manifattura Tabacchi industrial site design concepts.

Redevelopment activities are also carried out on the facades and roofs of the pre-existing warehouses through the insertion of double-skin technologies that provides to shield and aesthetically modify sheds facades and horizontal glazed solutions that favourites natural ventilation and lighting of spaces. Finally, in this first compositional solution an average extensive distribution of the green areas and public spaces is hypothesized, with a first subdivision into gardens, rest surfaces and walking routes;

2) The second design proposal reduces the square meters of added surface to leave more space and importance to urban green areas and spaces for social relationships. A large square, inserted in the eastern part of the disused lot, performs the function of a place of comparison, socialization and connector between the converted buildings. Unlike the first solution, in this scenario courts and corridors are created in the largest shed through an 'acupuncture' process, and in the last built industrial warehouse of Manifattura Tabacchi site with its division in two separate volumes. An observation tower, a small residential volume on the west side of site main entrance and a shed symmetrically juxtaposed with the pre-existing technical and plants compartment constitute the only architectures added in this purpose. Technological façade, roofing and connection solutions between interior rooms are adopted to improve the aesthetic quality, the liveability of the spaces and refurbished building performances. With regard to the layout of outdoor spaces, this second compositional solution, incorporates a wider distribution of areas of equipped greenery and urban furniture;
3) The latest design scenario follows the line of a greener and more environmentalist approach. Firstly, this option gives importance to the monumental entrance linear building, freeing it from the surrounding and lateral pre-existing structures, and does not provide for any addition of envelopes and covered surfaces. The only additions included in the project are attributable to the ideation of a removable metallic reticular vertical structure, resuming the iconic architectural element of the chimney that distinguishes the production areas

and to the insertion of vertical and horizontal shielding domotic technologies, protecting the interiors from sun's rays and ensuring ventilation conditions and natural lighting. As a result, the design solution prefers the natural element as the main component to assess sustainability issues. Most of the industrial site surfaces are characterized by large green areas and parks, promoting the programming of educational functions even outdoors.

In order to determine the sustainability and effectiveness of each solution described and to achieve the goal of identifying the most congenial industrial reuse approach for conceiving educational-laboratory purposes, eight qualitative and quantitative design indicators emerged from the debate among the participants of the focus group.

All the obtained independent criteria are listed and described as follows:

01) Greenery: it considers the surfaces intended for urban and equipped green spaces and outdoor furniture, as well as all permeable land used for gardens and parks. The related quantitative scores are expressed in ranges varying from 0%-10% to 90%-100% based on the m^2 of surfaces of green areas present in the hypothesized solutions (maximum green surface: 140.000 m^2 = 100%);

02) Spaces accessibility: this parameter consists in the possibility for people with reduced or prevented motor or sensory ability to reach in tranquillity buildings functional units and to easily enjoy spaces and equipment in conditions of safety and autonomy. Three ranges are defined for this qualitative judgement parameter: i) Discrete, ii) Good, iii) Very good;

03) Security: understood both as the absence of threats and problems that can affect people's health and as the public awareness of the spaces safety favourites by the installation of technologies to safeguard society. The ranges identified for this criterion vary from: i) Medium, ii) High and iii) Very high;

04) Spaces liveability: this attribute describes the human actions that have changed, used and controlled physical conditions of nature to slowly estab-

lish an organized system of linked spaces, promoting reception, people relationships and social inclusion. This factor, like parameter 02, varies from: i) Discrete, ii) Good, iii) Very good;

05) Architectural quality: it concerns the aspects related to the aesthetic, formal and architectural design options adopted, considering the contemporary spatial and aggregating principles and the volumetric hypotheses in harmony with the factory surrounding context. Three ranges define this factor: i) Discrete, ii) Good, iii) Very good;

06) Economic feasibility: it consists in the evaluation of the economic components involved in adaptive reuse projects, as well as the practical possibility of carrying out industrial conversion intervention on the basis of preliminary monitoring actions. This parameter is composed by three different evaluation ranges: i) Low, ii) Medium, iii) High;

07) New built volumes: this qualitative criterion considers the cubic meters of built-up spaces added to the pre-existences of the decommissioned industrial site. The related quantitative ranges are expressed in ranges varying from 0%-10% to 90%-100% depending on the m^3 of new volumes inserted in each option described (maximum m^3 of new volumes hypothesised: 17.200 m^3 = 100%);

08) Job opportunity: the factor outlines the presence of circumstances or conditions attributable to the introduction of innovative functions that increase the available jobs in the local scenery. Analogously to the previous criteria three different ranges are identified: i) Medium, ii) High and iii) Very high.

Table 4.4.1-1 (Table 4.4.1-1) lists the raw values of each scenario considering all the accounted attributed highlighted from the focus group debate.

Once the evaluation components of the industrial site recovery and transformation alternatives have been defined and the score ranges of each of them have been specified, the next step provides for the graphical formulation of the value functions. Accurate and detailed comparisons and discussions between the stakeholders of the focus

group help to formulate the monotonous trends of the value functions graphs, converting the qualitative and quantitative data obtained from the evaluating process of design solutions, summarized in the raw value table, into numerical values, from 0 to 1. These scores represent the different level of influence of each judgement parameter on building conversion interventions. Figure 4.4.1-6 (Figure 4.4.1-6) illustrates the Value Functions related to each of the attributes considered in the case study adaptive reuse conversion architectural proposals. The interpolation of the data contained in the raw values table with the ranges identified in the value functions constitutes the first performance matrix evaluation of the design alternatives hypothesized for the strategic functional transformation of the former Manifattura Tabacchi industrial site. As explained in the Table 4.4.1-2 (Table 4.4.1-2), there is no scenario that prevails over the others in all the criteria identified by the methodology. It's, therefore, necessary to determine the trade-offs among judgement parameters through the calculation of criteria weights with the SWING Weight Method (Schuwirth et al., 2012).
The next step for ranking the alternatives to reuse the former Manifattura Tabacchi industrial site consists in the definition of set of criteria weights with respect to the decision problem. Using the SWING Weight Method approach, 12 different actors in the contexts of architecture, engineering, urban planning and refurbishment techniques have been questioned separately, asking them to estimate the influence of each attribute considered with its maximum value, in a range between 0 and 100. Table 4.4.1-3 (Table 4.4.1-3) summarizes all the answers obtained from the experts interviewed. As it is possible to notice from the set of weights extrapolated by the normalization of questionnaire scores, and enclosed in the second performance matrix (Table 4.4.1-4), all the stakeholders agreed in considering security and spaces accessibility as the most important attributes in the decision problem under examination. These considerations are reflected in the mean set of weights where the most important judgement criteria is security (13,4% of importance), followed respectively by spaces accessibility (13%), architectural quality (12,9%), spaces liveability (12,7%), job opportunity (12,5%), greenery (12,3%), economic feasibility (11,6%) and building new volumes (11,5%).The single judgement parameter of the first performance matrix is

interpolated with the obtained set of weights of the second performance matrix using additive assumption to measure the final value of the three scenarios.
The third evaluation performance matrix (Table 4.4.1-5) lists the overall scores obtained using the equation (Eq. 4.4.1-1):

$$V(B1) = \sum Wn * Vn(Bn) \qquad (4.4.1\text{-}1)$$

where:

V(B1) is the final rank of the alternative B1;

Wn is the weight assigned to the attribute n by the decision maker C1;

Vn(Bn) is the value function standardized score of scenarios B1 considering the attribute n.

Figure 4.4.1-7 (Figure 4.4.1-7) relates and ranks the three alternatives on the basis of the values described in the third performance matrix. From the obtained results it is possible to affirm that the second compositional solution is the best alternative according to ten experts out of twelve. Only two respondents of the focus group expressed a greater preference for the third solution, but just a little above to the second scenario. Moreover, the first alternative is not chosen by any respondent, although it offers more job opportunities, decreasing green external solutions, considered as fundamental by the respondents to achieve feasible adaptive reuse interventions.
The draft design and compositional solution identified by the MAVT and SWING methodology is illustrated in the Figure 4.4.1-8 (Figure 4.4.1-8). In addition, all the physical, technological, functional and social characteristics of the transformation scenario to adopt for the former Manifattura Tabacchi, as well as the data relating to the current conditions of the site are summarized and described in the building cataloguing sheet (Table 4.4.1-6). The information enclosed in this classification module represents the input data for the formulation of the adaptive reuse strategy in the building recovery table and for the estimation of the feasibility coefficient (f) and the risk entity (r) based on the emerged relationships between DCS categories and subcategories.

	01_Greenery	02_Spaces accessibility	03_Security	04_Spaces liveability	05_Architectural quality	06_Economic feasibility	07_New built volumes	08_Job opportunity
Scenario 1	60000 m²	Good	Very High	Good	Good	Medium	172000 m³	Very High
Scenario 2	109000 m²	Very Good	Very High	Very Good	Very Good	Medium	35000 m³	High
Scenario 3	140000 m²	Very Good	High	Very Good	Very Good	High	14000 m³	Medium

	01_Greenery	02_Spaces accessibility	03_Security	04_Spaces liveability	05_Architectural quality	06_Economic feasibility	07_New built volumes	08_Job opportunity
Scenario 1	0.5	0.5	1	0.5	0.5	0.5	0	1
Scenario 2	0.8	1	1	1	1	0.5	0.8	0.5
Scenario 3	1	1	0.5	1	1	1	1	0

	User 1	User 2	User 3	User 4	User 5	User 6	User 7	User 8	User 9	User 10	User 11	User 12
01. Greenery	100	100	100	90	100	90	90	70	80	70	50	50
02. Spaces accessibility	90	85	80	80	90	95	80	100	80	85	85	90
03. Security	95	100	100	90	100	90	70	100	70	90	82	90
04. Spaces liveability	85	80	85	75	70	85	90	100	75	85	92	90
05. Architectural quality	100	95	90	95	95	70	80	70	90	80	89	80
06. Economic feasibility	75	70	60	80	60	80	50	90	90	90	90	90
07. New built volumes	90	85	80	70	80	70	70	90	70	70	80	70
08. Job opportunity	100	100	95	90	90	100	40	50	90	80	95	80

	User 1	User 2	User 3	User 4	User 5	User 6	User 7	User 8	User 9	User 10	User 11	User 12	Mean
01. Greenery	0.136	0.140	0.145	0.134	0.146	0.132	0.158	0.104	0.124	0.108	0.075	0.078	**0.123**
02. Spaces accessibility	0.122	0.119	0.116	0.119	0.131	0.140	0.140	0.149	0.124	0.131	0.128	0.141	**0.130**
03. Security	0.129	0.140	0.145	0.134	0.146	0.132	0.123	0.149	0.109	0.138	0.124	0.141	**0.134**
04. Spaces liveability	0.116	0.112	0.123	0.112	0.102	0.125	0.158	0.149	0.116	0.131	0.139	0.141	**0.127**
05. Architectural quality	0.136	0.133	0.130	0.142	0.139	0.103	0.140	0.104	0.140	0.123	0.134	0.125	**0.129**
06. Economic feasibility	0.102	0.098	0.087	0.119	0.088	0.118	0.088	0.134	0.140	0.138	0.136	0.141	**0.116**
07. New built volumes	0.122	0.119	0.116	0.104	0.117	0.103	0.123	0.134	0.109	0.108	0.121	0.109	**0.115**
08. Job opportunity	0.136	0.140	0.138	0.134	0.131	0.147	0.070	0.075	0.140	0.123	0.143	0.125	**0.125**

	User 1	User 2	User 3	User 4	User 5	User 6	User 7	User 8	User 9	User 10	User 11	User 12	Mean
Scenario 1	0.571	0.580	0.583	0.582	0.580	0.588	0.535	0.545	0.570	0.577	0.573	0.578	**0.57**
Scenario 2	0.829	0.829	0.836	0.825	0.838	0.821	0.865	0.848	0.814	0.826	0.821	0.830	**0.83**
Scenario 3	0.799	0.790	0.790	0.799	0.796	0.787	0.868	0.851	0.806	0.808	0.795	0.805	**0.81**

Tables 4.4.1-1; 2; 3; 4; 5 Raw values table; Standardised scores of alternatives; Experts questionnaire answers; Sets of weights provided by the experts; Overall values of scenarios.

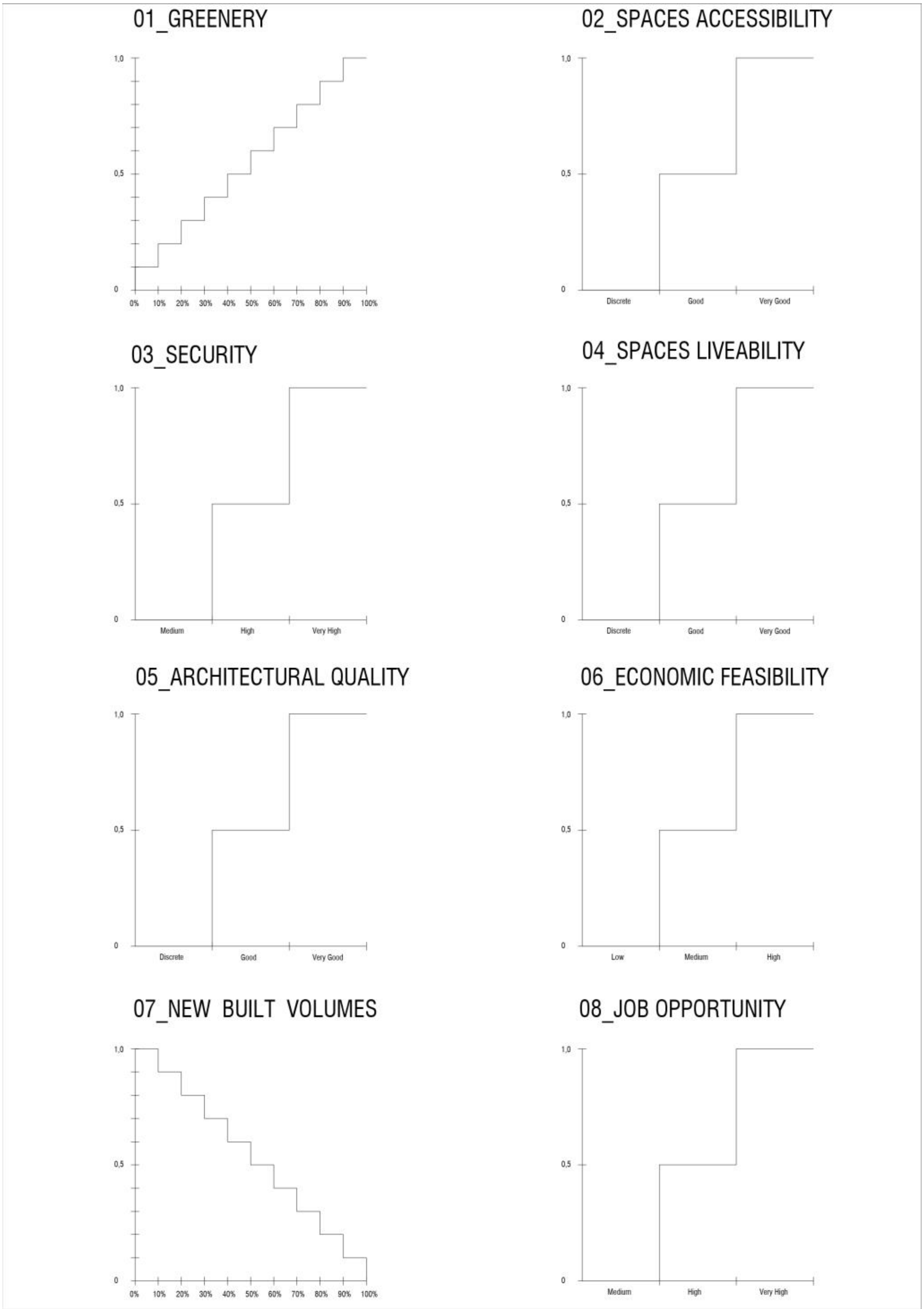


Figure 4.4.1-6 Former Manifattura Tabacchi industrial site elicitation of value functions for each attribute.

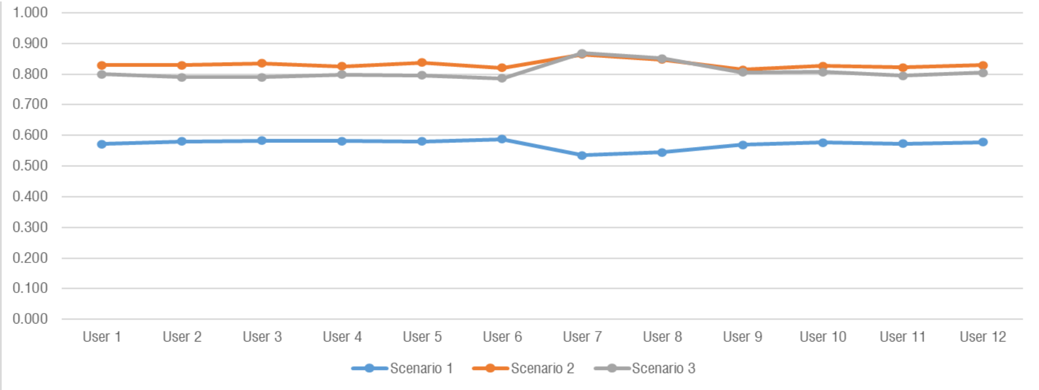


Figure 4.4.1-7 Ranking of the design alternatives for each user involved.

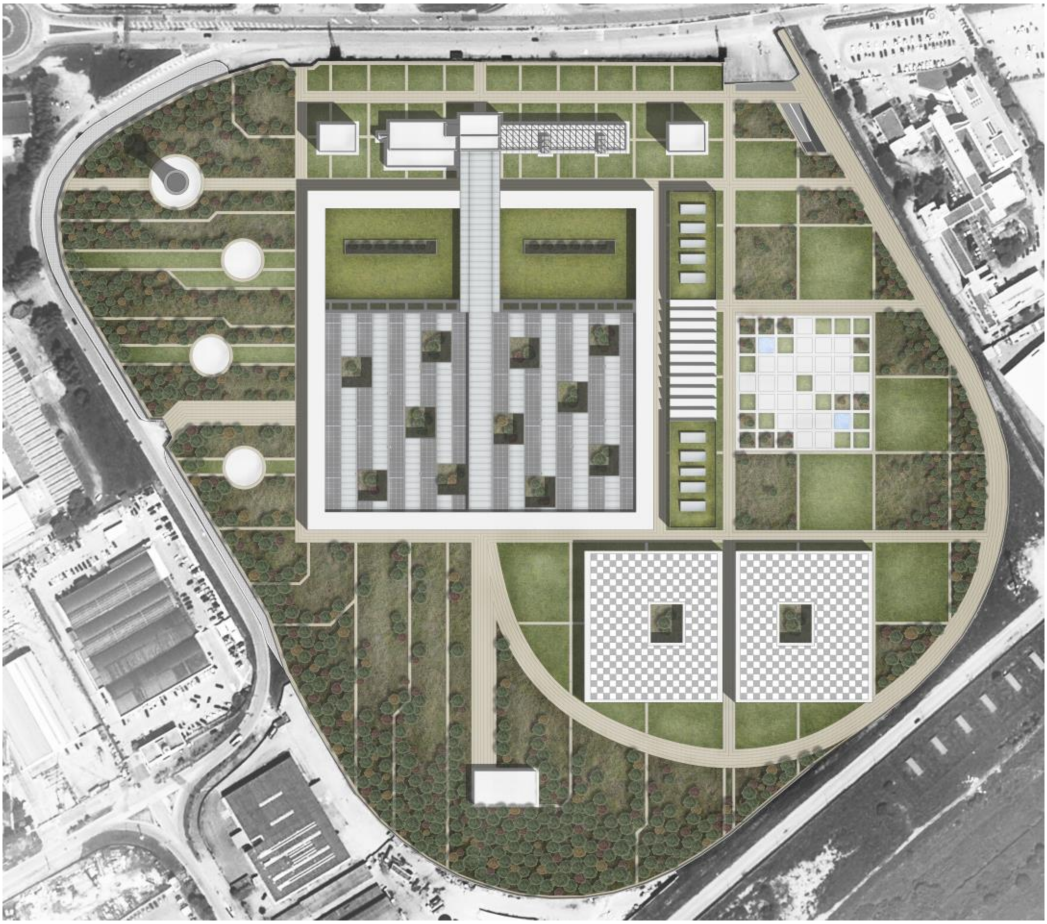


Figure 4.4.1-8 Design proposal of the selected architectural alternative for the transformation of the former Manifattura Tabacchi industrial site (Authors: Spadafina D. and Vizzarri C.).

General Data			
Building/site name	Former Manifattura Tabacchi industrial site	Climatic zone	C
City	Bari	Orientation	North-South
Region	Puglia	Number of entrances	4
Nation	Italy	Landscape quality	*Low*
Address	Francesco de Blasio Street, 22, Consortium ASI (BA)	Building Size	*Big*
Site location	41°06'53"(N), 16°48'30"(E)	Site surface (m^2)	210.000
Years of construction and dismission	1961,1977,1984/2006	Building surface (m^2)	67.810
Distance from city center	8,5 km (17 min)	Total volume (m^3)	551.540
Number of existing buildings	17	Level of maintainablity	Site =*low*
Number of historic buildings	1		Context =*low*
Building structural typology	Reinforced concrete, prefabricated panels and steel structures		Infrastructures =*medium*
Green areas (m^2)	69.500	Reclamation interventions	*No*
Public space (m^2)	62.690	Glazed surface	*Medium*

Existing buildings data					
Building Surfaces (m^2)	Building 1	100	Volumes (m^3)	Building 1	400
	Building 2	400		Building 2	1800
	Building 3	3600		Building 3	31200
	Building 4	450		Building 4	9000
	Building 5	100		Building 5	400
	Building 6	13000		Building 6	98500
	Building 7	1650		Building 7	9900
	Building 8	900		Building 8	4050
	Building 9	30000		Building 9	255000
	Building 10	500		Building 10	3000
	Building 11	500		Building 11	3000
	Building 12	60		Building 12	240
	Building 13	300		Building 13	1500
	Building 14	850		Building 14	4250
	Building 15	150		Building 15	675
	Building 16	250		Building 16	1125
	Building 17	15000		Building 17	127500
Heights (m)	Building 1	4	Number of floors	Building 1	1
	Building 2	4.5		Building 2	1
	Building 3	8.7		Building 3	3
	Building 4	20		Building 4	6
	Building 5	4		Building 5	1
	Building 6	7.6		Building 6	1
	Building 7	6		Building 7	1
	Building 8	4.5		Building 8	1
	Building 9	8.5		Building 9	1
	Building 10	6		Building 10	1
	Building 11	6		Building 11	1
	Building 12	4		Building 12	1
	Building 13	5		Building 13	1
	Building 14	5		Building 14	1
	Building 15	4.5		Building 15	1
	Building 16	4.5		Building 16	1
	Building 17	8.5		Building 17	1

Physical analysis					
Existing abandoned industrial site					
Level of decay	Site	*high*	Dampness	*medium*	Presence of constraints
	Buildings	*medium*	Pests	*low*	
	Materials	*medium*	Natural attack	*medium*	Lack of windows and finitures, collapses, presence of damaged railway tracks, high fences, no maintainance, proximity to the Lamasinata canal (hydrogeological constraint)
	Structures	Pillars = *medium*	Existing plants	Water system	
		Beams = *medium*		Heating and cooling system	
		Walls = *high*		Electric system	
		Vertical connections = *medium*		Exhaust system	
		Foundation = *medium*	Site conditions	Soil type	Consolidated
		Floor = *low*		Presence of vegetation	*medium*
		Roof = *high*		Level of traffic	Car = *high*
		Joints = *medium*			Bike = *low*
		Facade = *high*			Bus = *medium*
	Plants	*medium*			Camion = *high*
	Technologies	*medium*			Train = *low*
	Functional decay	Parking areas = *medium*			Pedestrian = *low*
		Space dimensions = *low*			Electric vehicles= low
		Flows management = *low*		Level of pollution	Environmental=*high*
	Green areas	*medium*			Acoustic=*medium*
	Context	*medium*			Water=*high*
Level of humidity	*medium*				Soil=*medium*
Presence of asbestos	*madium/low*				Light=*low*
Lack of building parts	*medium*				Air=*medium*
Project					
Buildign transformation interventions	Cladding	*Yes*		Subtraction	*Yes*
	Interior design	*Yes*		Demolition	*Yes*
	Addition	Connection	*Yes*	Envolve	*No*
		Merge	*No*	Outside	*Yes*
		Elevation	*Yes*	Connection through public space	*Yes*
		Intrusion	*Yes*	Landscape and urban art	*Yes*
		Stack	*No*		
		Duplication	*Yes*	Excavation	*No*
N. of new buildings	4		M² added surfaces	6800	
N. of refurbished buildings	6		M³ added volumes	35000	
N. of demolished buildings	11		Insertion of new openings	*No*	
New buildings project data					
Building Surfaces (m²)	Building 1	200	Volumes (m³)	Building 1	0
	Building 2	400		Building 2	8000
	Building 3	4200		Building 3	15000
	Building 4	2000		Building 4	12000
Heights (m)	Building 1	40	Number of floors	Building 1	10
	Building 2	20		Building 2	6
	Building 3	3.6		Building 3	1
	Building 4	6		Building 4	1
Functional analysis			**Social analysis**		
Space flexibility and convertibility	*high*	*high*	Stakeholders involved	Project manager, facility manager, site manager, Bim manager, consultants, inventors, developers, architects, engineers, graphic designers, construction team, workers, technicians, geologist, urbanists, sub-contractors, landscapers, pollution manager, regulators, public administration, municipal council, regional council, professors, heritage consultant, owners, promoters, investors	
Main functions	Function category	Specific function			
	Cultural	Conference center, library, student center, university lab, science laboratories, research center			
	Residential	Hotel, students rooms			
	Commercial	Bar, restaurant, bookshop			
	Offices	Co-working spaces, hubs, smart office,			
	Sporty	Sport center, gym, playground			
	Education	University, workshop, education center			
	Public spaces	Park, square, community center, meeting rooms, parking areas			
	Spaces for healthcare	Analysis center, pharmacy			
N. of services	29				
Level of accessibility and connectivity	*high*	*medium*			
Spatial flow management	*high*		Users	Students, professors, associations, developers, scientists, workers, community, neighbors	
Dismantlability	*medium*				
Project building total surface (m²)	67.000				
Project green areas (m²)	109.000				

<table>
<tr><td>Project public spaces (m²)</td><td colspan="2">34.000</td><td rowspan="7">Population needs</td><td colspan="2" rowspan="7">Increase of public spaces, increase of services, increase of green spaces, increase of infrastructures, job opportunities, increase district security</td></tr>
<tr><td rowspan="8">Distance from points of interest</td><td>Points of interest</td><td>Distance (Km)</td></tr>
<tr><td>Airport</td><td>8</td></tr>
<tr><td>Team Theater</td><td>13</td></tr>
<tr><td>Polytechnic of Bari</td><td>12</td></tr>
<tr><td>Pane e Pomodoro beach</td><td>14</td></tr>
<tr><td>Stadium S. Nicola</td><td>6</td></tr>
<tr><td>S. Girolamo beach</td><td>5</td><td>Site importance for society</td><td colspan="2">high</td></tr>
<tr><td>Petruzzelli Theater</td><td>8</td><td>Usability and liveability</td><td colspan="2">high</td></tr>
<tr><td rowspan="5">Building connectivity</td><td>Points of interest</td><td>medium</td><td>Site aesthetic identity</td><td colspan="2">medium</td></tr>
<tr><td>Parking areas, public spaces and green areas</td><td>high</td><td>Site attractiveness</td><td colspan="2">medium</td></tr>
<tr><td>City centre</td><td>low</td><td>Relation society-environment-building</td><td colspan="2">high</td></tr>
<tr><td>Waterfront</td><td>medium</td><td>Social inclusion</td><td colspan="2">high</td></tr>
<tr><td>Main services</td><td>medium</td><td>Social participation</td><td colspan="2">medium</td></tr>
<tr><td colspan="6">Other information</td></tr>
<tr><td>Economic feasibility</td><td>low</td><td>Political feasibility</td><td>medium</td><td>Investments</td><td>high and public/private</td></tr>
<tr><td>Applied materials</td><td>Sand, gravel, expanded clay, recycled metal, iron, steel, aluminium, galvanized steel, concrete, lightweight concrete, fiber reinforced concrete, gres, granite, rock wool, glass wool, low-emissive glass, reflective glass, thermochromic glass, plastic materials, paints, neoprene, plaster, mortar</td><td>Implemented technologies</td><td>Water management, shieldings, photovoltaic system, heating and cooling, electrical system, ventilation system, waste treatment plant, exhaust system, wind power plant, double-skin facade, green facade, thermochromic glass, collector glass, low-emissive glass, vertical brise soleil, curtains, green panels, microperforated metal, thermal insulation, acoustic insulation, natural ventilation, natural lighting, insulated walls, ventilated facade, bioclimatic facade, structural glass facade, radiant floors, prefabricated slabs, false sealing for installations, seismic joints, earthquake resistant foundation, stairs, lifts, catwalks, photovoltaic roof</td><td>Security and safety systems</td><td>Alarm system, domotic system, cameras, sensors, compartimentalization, fire resistant walls, escape routes and stairs, fireproof doors, open spaces, spaces for collectivity on multiple levels</td></tr>
<tr><td colspan="6">S.W.O.T. Analysis</td></tr>
<tr><td colspan="3">Strenghts</td><td colspan="3">Weaknesses</td></tr>
<tr><td colspan="3">Site uniqueness in the local territory; high flexibility and accessibility of spaces; presence of extended volumes to use; technological and education sectors are constantly developed in the city of Bari; specialistic training workshops for inhabitants and workers; strategic position of the lot in the peripheral urban context; proximity to high-flowing roads; iconic site of the ASI Consortium urban evolution</td><td colspan="3">Impact of construction costs for project realisation; low importance given to technology and researches fields by the inhabitants; lack of economic resources; high level of degradation and neglect of structures; damaged façade elements; collapsed building parts; prostitution</td></tr>
<tr><td colspan="3">Opportunities</td><td colspan="3">Threats</td></tr>
<tr><td colspan="3">New job opportunities; efficiency of abandoned buildings; improvement of soil permeability capacity; introduction of large areas to be devoted to urban greenery and public spaces for the community; introduction of new primary services for the society; prestige for the Municipality of Bari and the Puglia region for the regeneration of the disused industrial site with a view to the development of teaching functions; possibility of strengthening iterations between students and pharmaceutical, biotechnology and chemical companies; improvement of the liveability of the Consortium's spaces and social interactions between surrounding neighborhoods</td><td colspan="3">Increasing competition from other countries; strengthening the trend of abandonment of rural areas; lack of public or private entities willing to invest in interventions involving metropolitan suburbs; difficulties in managing spaces; difficulties in managing the design, maintenance and monitoring phases; long implementation times</td></tr>
<tr><td colspan="6">Risks</td></tr>
<tr><td colspan="6">Asbestos, collapses, vandalism, building defections, building vulnerability, hazards, increasing of project and construction times, increasing of bureaucratic times, construction errors, increasing of construction costs, lack of investments, accidents at work</td></tr>
</table>

Table 4.4.1-6 Building cataloguing sheet (Former Manifattura Tabacchi industrial site).

4.4.2 *The former Radaelli Sud Factory*

The second disused peripheric industrial site considered for the application of the Decision Support System, described in the previous paragraphs and in the chapter 03, concerns the sustainable conversion of the former Radaelli Sud factory. It can be accounted as an historic example of industrial modern archaeology that influence the evolution of the entire ASI Bari/Modugno Consortium. This big industrial complex of about 110.000 sqm of surface, built in the first half of the 1970s (1971), contained activities aimed at the manufacture of stationary compressors and roundups. Following a decline in production and consequent failure of the company, the industrial complex stopped working in 2014. The abandoned factory occupies a central position in the Bari/Modugno industrial area, since it is not only closely linked to one of the main road slides inside the ASI Consortium production site (Francesco De Blasio Street), but also it is located in a central and strategic point within the productive context (Figures 4.4.2-1; 2).

Figure 4.4.2-1 Former Radaelli Sud factory location in the ASI Consortium area.

Figure 4.4.2-2 Former Radaelli Sud factory aerial view (Source: Google Earth Pro).

Concerning the physical and structural conditions of the warehouses established in the former Radaelli Sud factory lot, the on-site inspection of the individual building components and prospective display of surfaces and volumes through virtual and graphic software (Google Earth Pro, AutoCad and Rhinoceros) (Figures 4.4.2-3; 4) guarantee to diagnose a slight level of decay of the existing built fabric and context, as well as the spatial and dimensional relationships between the sheds characterizing the disused site. The only pathologies detected by the screening phase can be synthesized in limited and restricted areas of worn plaster involving external wall vestments, facades chromatic alterations, presence of widespread oxidation on the metal building components and high carelessness of the external areas due to a total absence of maintenance activities in the post-divestment years. From a compositional and spatial point of view, the complex includes five main structures: a central warehouse for goods production and storage, two directional buildings, an independent concierge overlooking the factory entrance and a small parallelepiped envelope adjacent to the main volume attributable to a subsequent expansion plan of the plant. Three of these (the central shed and the office buildings characterising the street front) incorporate formal-architectural values attributable to the typical industrial structures of the 1960s and 1970s, characterized by a reinforced concrete bearing structure, metal reticular beams and shed roofs.

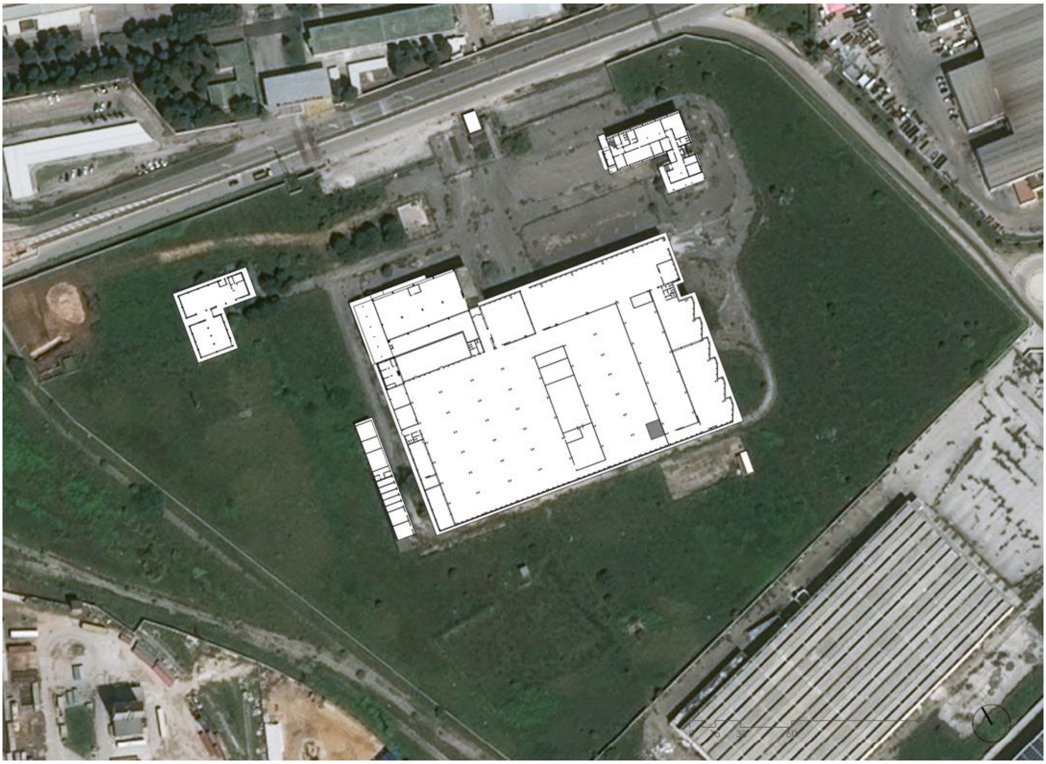


Figure 4.4.2-3 Existing former Radaelli Sud factory morphology.

Unlike the previous case study, the following strategic reuse intervention uses the MAVT approach to estimate the most suitable functional program to particularise the disused industrial buildings of the former Radaelli site, considering as decision objective the creation of a technological, cultural and innovation hub to entrench, in the city marginal districts, incubators, start-ups, spin-offs and coworking spaces in close correlation with augmented reality laboratories and exhibition spaces. These functional scenarios result not only smart and futuristic containers of promoting and inventing advanced and virtual tools and apps in the digital field, but also places of cultural and data exchange between IT experts and services that can attract curious people of different ages, discovering the modern frontiers of remote devices and information technology.

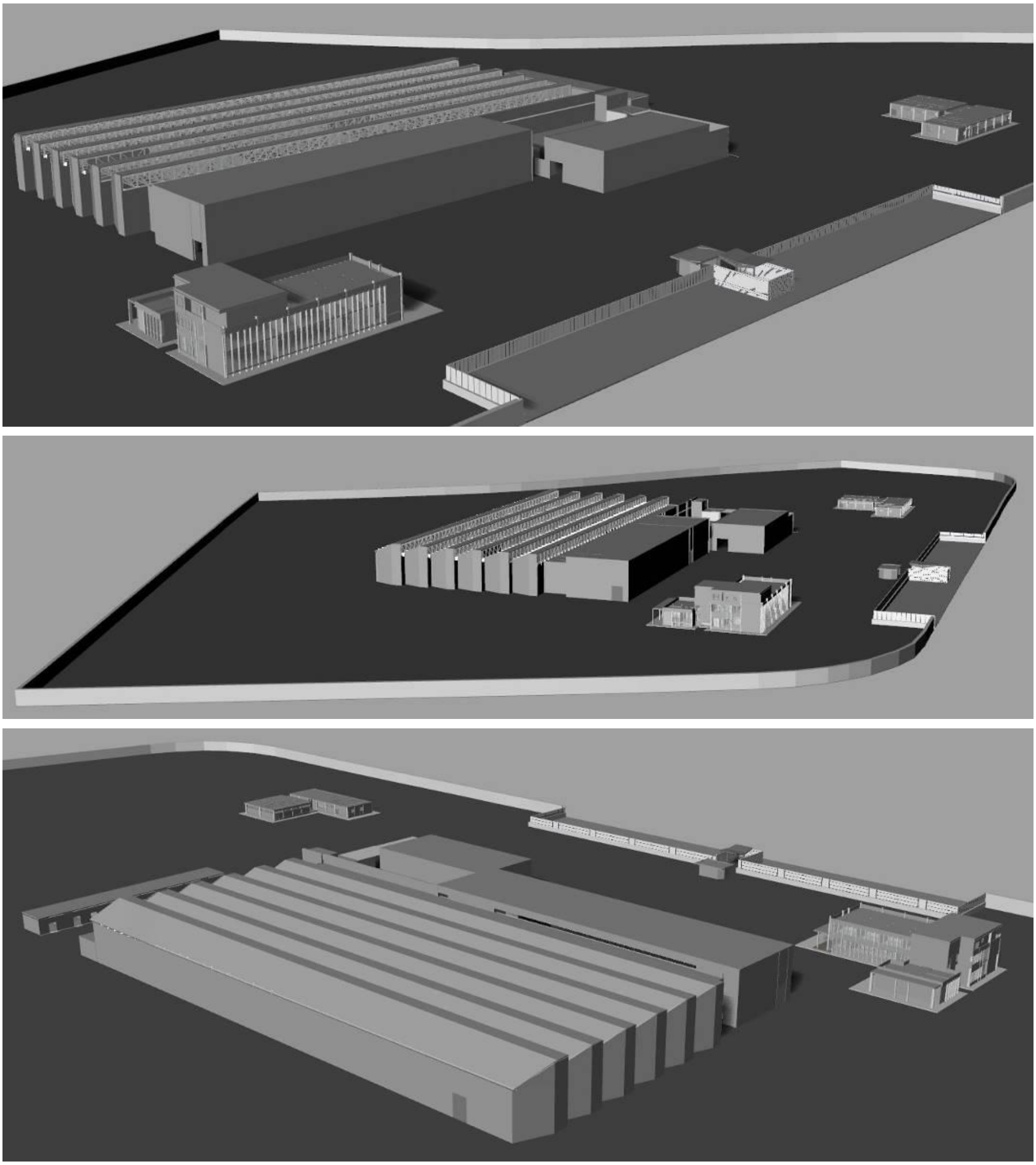


Figure 4.4.2-4 3D model interface of the existing buildings and warehouses included in the former Radaelli Sud factory (Software: AutoCad and Rhinoceros).

Private and public funding must be allocated, so that this avant-garde and future functional transformation of the industrial site can have a chance of implementation in the context of the ASI Consortium. In particular, municipal and regional public institutions and entrepreneurs in the field of Information Technology (IT) and innovation could be united by the interest in collaborating for the training on the territory of smart hubs that would implement the already existing Fiera del Levante Impact-Hub. The ability to correlate the phases of experimentation and development of virtual tools with the direct testing processes on users of the implemented technologies strengthens the interaction between developers and society, favouring market policies and product knowledge. Once the general framework of the existing context has been defined and the objective to be pursued for the conversion of the disused industrial site has been set, the next step provides for the formation of a focus group of 12 experts in recovery, architecture history, engineering, urban planning and Building Information Modeling (BIM) for the identification of efficient functional transformation choices of the disused production lot and judgement parameters with their respective value functions. The issues that have stir up the debate about the services and uses to include in the alternatives are due to the desire to hypothesize public spaces that promote situations of social inclusion and job opportunities in order to develop and make known to the community the future digital, IT and virtual reality technologies that could be introduced on the market in the coming years.

In particular, the three functional alternatives that emerged from the debate are listed and described as follows:

1) Composition of advanced coworking structures and smart offices, which not only provide to the development of innovative and dynamic work structures and configurations, but favour the mutual collaboration of multiple figures specialized in different sectors, contributing to a common purpose in the efficiency of architectural, technological, urban and home automation tools and components with the aim of guaranteeing high performance standards and quality. The introduction of shared smart working hierarchies strengthens the uniqueness of the processes of ideation, design and testing of the hypothesized innovative systems, shortening the interfacing times between different specialised figures involved and construction phases to perceive prototypes

manufacturing. The first functional choice, therefore, provides the construction of a complex of tertiary function buildings based on interconnected spaces that contain laboratories and modular compartments aimed at the conception, design, development, analysis of the performance of technological components, testing of prototypes and maintenance of home automation systems and inter-faces. Functions dedicated to the training and updating of staff and future workforces are not neglected;

2) Functional conversion of decommissioned industrial spaces into digital incubators and smart hubs through the installation of start-ups and spin-offs. In particular, this second functional option amplifies the development of small local companies that want to enter in the digital market world on the basis of an innovative, actual and original virtual idea or social app. The programme of activities envisaged strengthens and eradicate the iterations between developers, expanding the knowledge regarding the avant-garde technological and virtual frontiers and modern users' trends. In accordance to the purely advanced tertiary function, a part of the proposed scenario includes the desire to make citizens, fans, experts and scholars in the fields of information and digital technologies, able to collaborate and increase their skills and knowledge through the promotion of interactive workshops that expose topics related to sustainable urban design, modelling and 3D printing, modern diagnostic methods, monitoring and resistance measurements on materials, passive surveillance systems and remote technologies;
3) The third functional option combines the activities described above with a purely exhibition and museum function that allows to illustrate through augmented reality technologies, touch panels and interactive screens the evolution of technologies over time. This interesting design of existing spaces relates the working environment with the cultural teaching and learning sphere. The environment is perceived not only as a place of idea production and work, but as a multifunctional structure that can increase the attractiveness of the industrial urban periphery and the social relationships between visitors that

admire and surf in the digital and internet world and inventors who compute and test future social and viral apps that will invade our daily lives.

In order to adopt a pondered and consistent ranking of the best functional solution to be adopted in the analysed context, the active participation of the focus group experts contributed to the definition of eight independent qualitative and quantitative parameters:

01) Site attractiveness: it regards the ability to attract a large number of people thanks to the intrinsic characteristics of the site and the proposed functional program. The related qualitative ranges varying from: i) Moderate, ii) More or less good, iii) Good, iv) Very good and v) Perfect;
02) Job opportunity: the parameter refers to the possibility of generating new jobs in the local territory according to well-structured and profitable services. Five ranges define this criterion: i) Very low, ii) Low, iii) Medium, iv) High and v) Very high;
03) Number of services: it is intended as the amount of micro-functions enclosed within the characterizing macro-function. This quantitative assessment criterion is estimated on the basis of the number of services assumed in each generic functional thematic typology identified and varies from 0 to 21;
04) Flows management: This judgement parameter can be defined as the ability to adjust the amount of incoming and outgoing workers and users in terms of space and time, depending on the assumed functions. Analogously to the first parameter five different ranges are identified: i) Moderate, ii) More or less good, iii) Good, iv) Very good and v) Perfect;
05) Profitability: the criterion is described as the ability to get profits from the activities established in the industrial external and internal surfaces involved in the adaptive reuse interventions. The ranges identified for this criterion vary from: i) Moderate, ii) Good, iii) Very good and iv) Perfect;
06) People safety and security: this evaluation attribute takes into account the rules on people safety, social distancing and passive and home automation

technological systems that guarantee the use in total tranquillity of spaces and functions by users. Like the previous parameter, the values vary from: i) Moderate, ii) Good, iii) Very good and iv) Perfect;

07) Spaces liveability: this estimation factor defines the indoor and outdoor quality of the spaces, as well as the spatial comfort levels of the hypothesized functions in relation to spatial configurations. This factor, like the previous one, also varies from: i) Moderate, ii) Good, iii) Very good and iv) Perfect;

08) Number of people/sqm: this second quantitative parameter estimates the amount of people that each of the functions listed could host on the basis of the square meters useful per person and social distances standards. The related quantitative ranges are expressed in ranges varying from 0 to 3850 people/sqm (100%), based on the calculated social density value of the single functional proposal.

Table 4.4.2-1 (Table 4.4.2-1) provides the raw values of each functional alternative for all the considered attributes arisen by the focus group discussion. The next steps for the evaluation and classification of adaptive reuse explained functional scenarios follow the decision support approach formulated and detailed in the previous paragraph and in the methodology set out in chapter 3. In particular, the decision support process is structured as follows:

a) Definition and graphic design, through experts discussions, of the monotonic trends of value functions based on the ranges identified for each judgement parameter (Figure 4.4.2-5);
b) Interpolation of value functions numerical data with the scores contained in the raw value table and subsequent formulation of the first performance matrix (Functional solutions – Judgement parameters) (Table 4.4.2-2). This second multicriteria decision-making analysis doesn't show a scenario that prevails on all the judgement evaluation parameters identified;
c) Attributes weights evaluation using the SWING Weight Method. Twelve actors are interviewed to estimate the judgement criteria, formulating the sets of

weights useful to classify the potential of each functional solution. Table 4.4.2-3 (Table 4.4.2-3) lists the answers provided by stakeholders regarding the estimation of the independent parameters considered for the former Radaelli factory case study. In particular, the second performance matrix (stakeholders – functional alternatives) (Table 4.4.2-4) illustrates the stakeholders' preferences towards site attractiveness, people security and spaces liveability scopes with an average weights value of 13.3%;

d) Scores correlation process between the first and second performance matrix for the calculation of the final ranks of alternatives, using the additive method. The final results characterise the third performance matrix (functional scenarios - stakeholders) (Table 4.4.2-5).

From the obtained results it is possible to state that the third functional option corresponding to the virtual interactive hub and exhibition space is the best spatial programme according to eleven sets of weights out of twelve and it ranks second in the remaining set (Figure 4.4.2-6). According to the careful and accurate site surveys and contexts analyses and consequently to the results arisen from the methodology of the MAVT and SWING Weight Method, the preferable function that favours greater revenues, employment and tourists and users flows within the former Radaelli Sud plant regards the hypothesis of inserting interactive exhibition and museum spaces based on virtual and digital reality and dynamic, and modular smart offices for the active and mutual sharing of knowledge and integrated development of avant-garde remote sensing and digital apps and devises for future generations. The adaptive reuse design solution of the best alternative arisen from the decision support analysis is graphically shown in Figure 4.4.2-7 (Figure 4.4.2-7). In addition, quantitative and qualitative data respectively of the characteristics of the existing warehouses fabric and the scenario architectural, functional and social features are schematizes in the corresponding building cataloguing sheet (Table 4.4.2-6). The latter scheme incorporates the input data to be included in the DCS multicriteria structure for the calculation of the feasibility coefficient (f) of adaptive reuse intervention and the risk entity (r).

	01. Site attractiveness	02. Job opportunity	03. Number of services	04. Flows management	05. Profitability	06. Security	07. Spaces liveability	08. Number of people/m^2
A. Coworking areas/Smart Office	More or less good	High	13	More or less good	Very good	Very Good	Good	3850
B. Start up/Spin Off	Good	Very high	21	Good	Good	Perfect	Perfect	2200
C. Smart hubs and interactive exhibition spaces	Perfect	Medium	16	Very good	Perfect	Very Good	Very Good	1650

	01. Site attractiveness	02. Job opportunity	03. Number of services	04. Flows management	05. Profitability	06. Security	07. Spaces liveability	08. Number of people/m^2
A. Coworking areas/Smart Office	0.25	0.75	0.65	0.25	0.667	0.667	0.333	1
B. Start up/Spin Off	0.5	1	1	0.5	0.333	1	1	0.5
C. Smart hubs and interactive exhibition spaces	1	0.5	0.8	1	1	0.667	0.667	0.332

	User 1	User 2	User 3	User 4	User 5	User 6	User 7	User 8	User 9	User 10	User 11	User 12
01. Site attractiveness	90	95	90	95	95	75	80	100	80	90	75	80
02. Job opportunity	80	85	80	95	90	95	90	80	70	80	95	90
03. Number of services	90	90	70	80	55	80	85	80	80	90	90	90
04. Flows management	85	90	75	60	75	80	85	60	65	75	90	95
05. Profitability	75	85	80	80	90	90	90	90	80	90	95	90
06. Security	100	100	95	95	100	95	95	80	65	85	82	90
07. Spaces liveability	80	85	90	80	90	90	85	100	80	90	92	90
08. Number of people/m^2	70	75	55	50	65	80	100	80	80	75	90	80

	User 1	User 2	User 3	User 4	User 5	User 6	User 7	User 8	User 9	User 10	User 11	User 12	Mean
01. Site attractiveness	0.134	0.135	0.142	0.147	0.144	0.109	0.148	0.149	0.133	0.133	0.106	0.113	**0.133**
02. Job opportunity	0.119	0.122	0.126	0.147	0.136	0.139	0.121	0.119	0.117	0.119	0.134	0.128	**0.127**
03. Number of services	0.135	0.128	0.11	0.128	0.083	0.117	0.121	0.119	0.133	0.133	0.127	0.128	**0.122**
04. Flows management	0.128	0.128	0.118	0.095	0.114	0.117	0.085	0.091	0.109	0.111	0.127	0.134	**0.113**
05. Profitability	0.112	0.122	0.126	0.126	0.136	0.131	0.135	0.135	0.133	0.133	0.134	0.128	**0.129**
06. Security	0.149	0.143	0.149	0.147	0.153	0.139	0.121	0.119	0.109	0.127	0.116	0.128	**0.133**
07. Spaces liveability	0.119	0.121	0.142	0.128	0.136	0.131	0.148	0.149	0.133	0.133	0.129	0.128	**0.133**
08. Number of people/m^2	0.104	0.101	0.087	0.082	0.098	0.117	0.121	0.119	0.133	0.111	0.127	0.113	**0.109**

	User 1	User 2	User 3	User 4	User 5	User 6	User 7	User 8	User 9	User 10	User 11	User 12	Mean
A. Coworking areas/Smart Office	0.560	0.558	0.549	0.561	0.557	0.578	0.569	0.565	0.573	0.565	0.578	0.567	**0.56**
B. Start up/Spin Off	0.742	0.737	0.612	0.754	0.731	0.741	0.733	0.730	0.724	0.734	0.734	0.735	**0.73**
C. Smart hubs and interactive exhibition spaces	0.755	0.758	0.760	0.755	0.754	0.739	0.745	0.748	0.745	0.753	0.741	0.750	**0.75**

Tables 4.4.2-1; 2; 3; 4; 5 Raw values table; Standardised scores of alternatives; Experts questionnaire answers; Sets of weights provided by the experts; Overall values of scenarios.

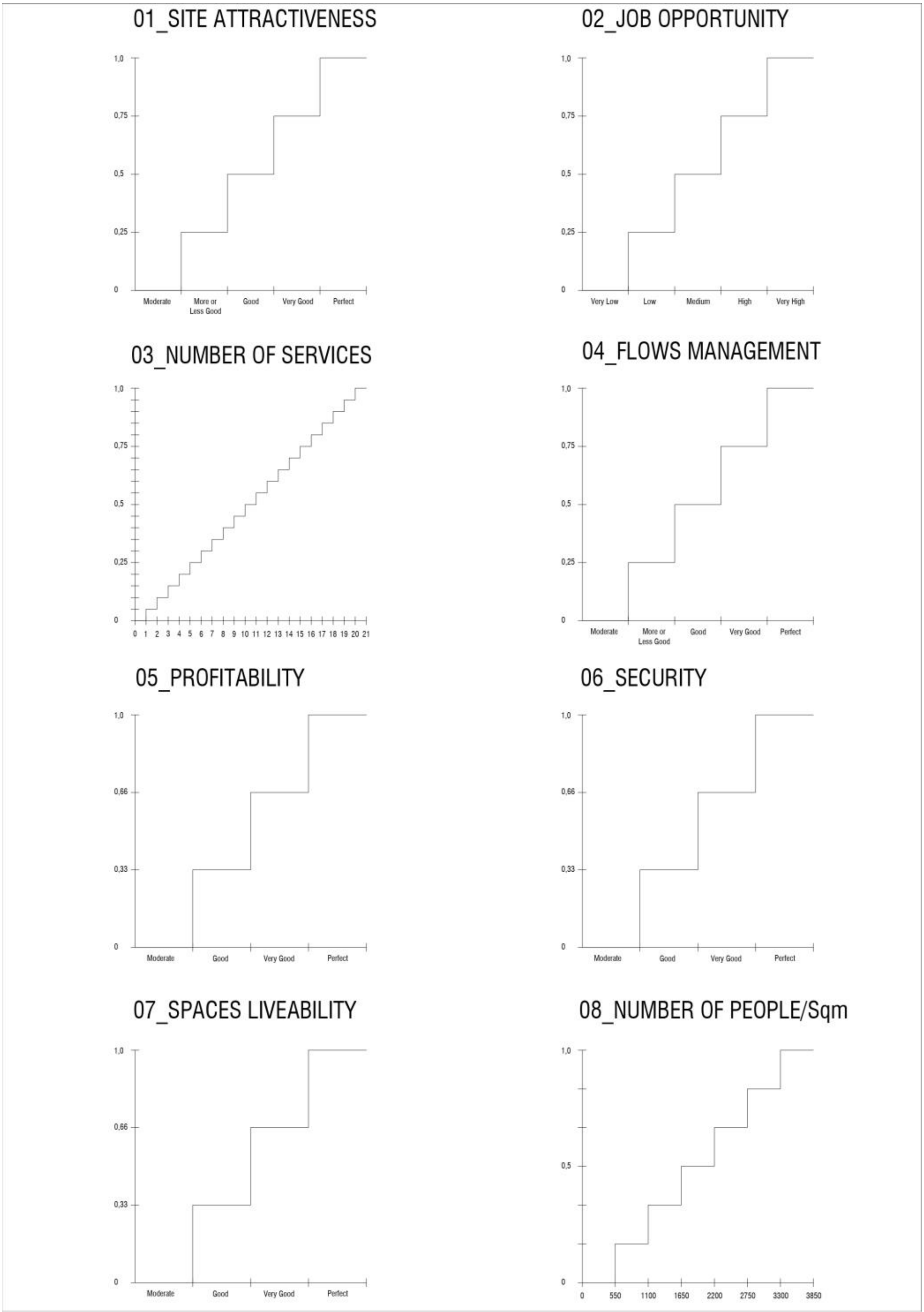


Figure 4.4.1-5 Former Radaelli Sud factory elicitation of value functions for each attribute.

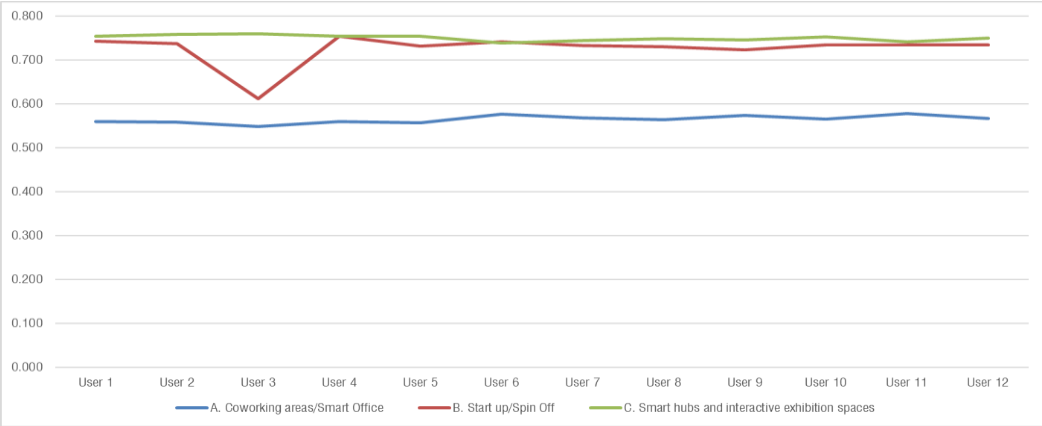


Figure 4.4.2-6 Ranking of the design alternatives for each user involved.

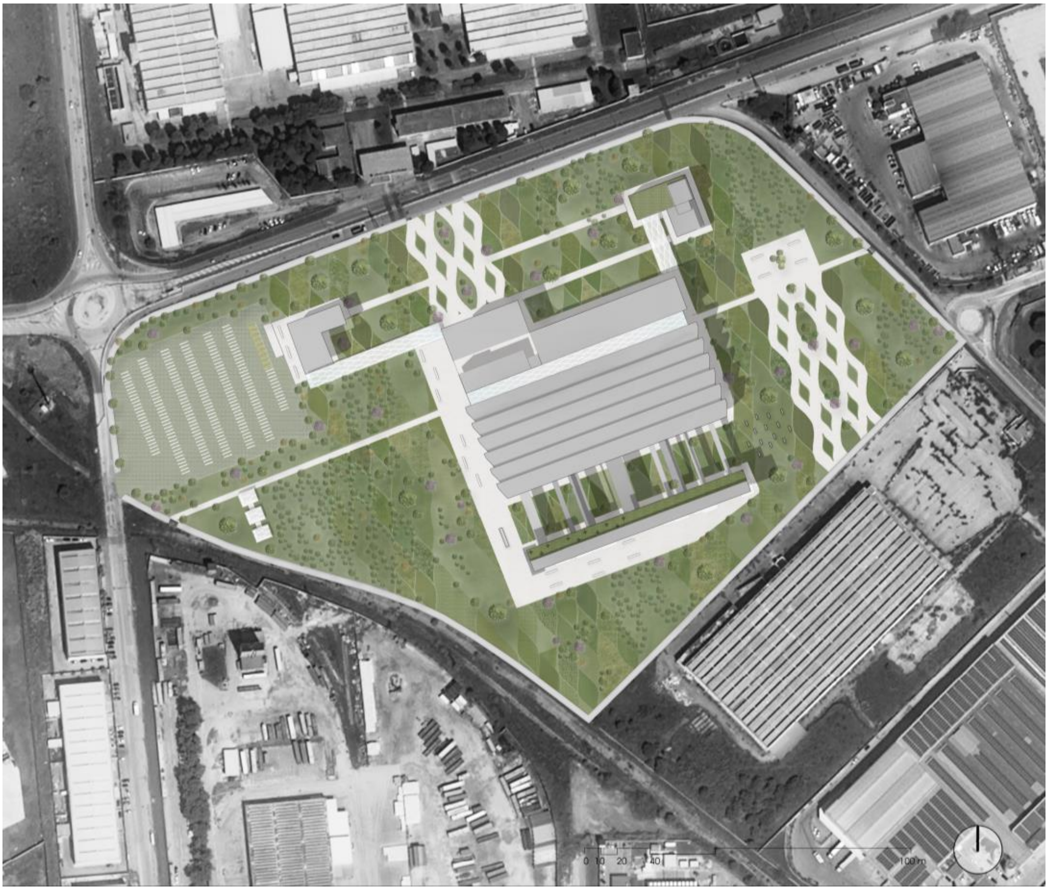


Figure 4.4.2-7 Design proposal of the selected architectural alternative for the conversion of the former Radaelli Sud factory (Authors: Roncone R. T. and Vizzarri C.).

General Data					
Building/site name	Former Radaelli Sud factory		Climatic zone	C	
City	Bari		Orientation	North - South	
Region	Puglia		Number of entrances	1	
Nation	Italy		Landscape quality	*Medium*	
Address	Francesco De Blasio Street, 36, 70026, ASI Consortium		Building Size	*Big*	
Site location	41°06'40.3"N 16°47'29.6"E		Site surface (m²)	108.500	
Years of construction and dismission	1971/2014		Building surface (m²)	16.200	
Distance from city center	11 km (15 min)		Total volume (m³)	206.940	
Number of existing buildings	5		Level of maintainablity	Site =*medium*	
Number of historic buildings	3			Context =*medium*	
Building structural typology	Reinforced concrete and metal reticulated beams			Infrastructures =*high*	
Green areas (m²)	75.400		Reclamation interventions	*No*	
Public space (m²)	16.900		Glazed surface	*Low*	
Existing buildings data					
Building Surfaces (m²)	Building 1	14.165	Volumes (m³)	Building 1	186.978
	Building 2	1.135		Building 2	12.712
	Building 3	900		Building 3	3.870
Heights (m)	Building 1	13.2	Number of floors	Building 1	1
	Building 2	11.2		Building 2	3
	Building 3	4.3		Building 3	1
Physical analysis					
Existing abandoned industrial site					
Level of decay	Site	*medium*	Dampness	*medium*	Presence of constraints
	Buildings	*medium*	Pests	*medium*	
	Materials	*medium*	Natural attack	*medium*	Relative proximity to the Lamasinata canal (hydrogeological constraint), proximity between buildings, different heights between buildings, distance from the main road, presence of high and opaque perimetral fences, limited volumes compared to the size of the lot, low maintenance
	Structures	Pillars =*low*	Existing plants	Electric system	
		Beams =*low*		Exhaust system	
		Walls =*medium*		Gas system	
		Vertical connections =*medium*		Ventilation, heating and cooling system	
		Foundation =*low*	Site conditions	Soil type	Consolidated
		Floor =*medium*		Presence of vegetation	*medium*
		Roof =*high*		Level of traffic	Car =*high*
		Joints =*medium*			Bike =*low*
		Facade =*medium*			Bus =*medium*
	Plants	*medium*			Camion =*high*
	Technologies	*medium*			Train =*low*
	Functional decay	Parking areas =*high*			Pedestrian =*low*
		Space dimensions =*low*			Other ….
		Flows management =*medium*		Level of pollution	Environmental=*medium*
	Green areas	*medium*			Acoustic=*high*
	Context	*low*			Water=*medium*
Level of humidity	*medium*				Soil=*medium*
Presence of asbestos	*low*				Light=*low*
Lack of building parts	*none*				Air=*medium*

Project					
Buildign transformation interventions	Cladding	*Yes*		Subtraction	*No*
	Interior design	*Yes*		Demolition	*Yes*
	Addition	Connection	*Yes*	Envolve	*No*
		Merge	*Yes*	Outside	*Yes*
		Elevation	*No*	Connection through public space	*Yes*
		Intrusion	*No*	Landscape and urban art	*Yes*
		Stack	*No*		
		Duplication	*No*	Excavation	*No*
N. of new buildings	1		M² added surfaces	990.6	
N. of refurbished buildings	3		M³ added volumes	13.076	
N. of demolished buildings	2		Insertion of new openings	*Yes*	
New buildings project data					
Building Surfaces (m²)	Building 1	990.6	Volumes (m³)	Building 1	13.076
Heights (m)	Building 1	13.2	Number of floors	Building 1	4
Functional analysis			**Social analysis**		
Space flexibility and convertibility	*high*	*high*	Stakeholders involved	Project manager, facility manager, site manager, Bim manager, consultants, inventors, developers, architects, engineers, graphic designers, construction team, workers, technicians,urbanists, landscapers, pollution manager, regulators, public administration, municipal council, regional council, professors, heritage consultant, owners, promoters, investors	
Main functions	Function category	Specific function			
	Cultural	Conference center, exhibition spaces,			
	Commercial	Bar, restaurant, bookshop			
	Offices	Co-working spaces, hubs, smart office,			
	Education	Workshops			
	Spaces for fun	Open-air event space, theme park			
	Public spaces	Park, meeting rooms, parking areas			
N. of services	16				
Level of accessibility and connectivity	*high*	*medium*			
Spatial flow management	*high*		Users	Students, professors, associations, developers, scientists, workers, community, IT engineers, start-uppers	
Dismantlability	*medium*				
Project building total surface (m²)	17.191				
Project green areas (m²)	80.900				
Project public spaces (m²)	10.409		Population needs	Increase of public spaces, increase of services, job opportunities, increase district security, increase public transports, spaces accessibility	
Distance from points of interest	Points of interest	Distance (Km)			
	Ferrarese square	11			
	Polytechnic of Bari	13			
	Pane e Pomodoro beach	22			
	S. Nicola stadium	6.6	Site importance for society	*medium*	
	Airport	7	Usability and liveability	*high*	
Building connectivity	Points of interest	*medium*	Site aesthetic identity	*medium*	
	Parking areas, public spaces and green areas	*high*	Site attractiveness	*medium*	
	City centre	*low*	Relation society-environment-building	*medium*	
	Waterfront	*medium*	Social inclusion	*high*	
	Main services	*medium*	Social participation	*high*	
Other information					
Economic feasibility	*medium*	Political feasibility	*medium*	Investments	*high and public/private*
Applied materials	Sand, gravel, wood, recycled metal, steel, aluminium, titanium, cast iron, concrete, lightweight concrete, gres, brick, rock wool, cellulose fibre, polyethylene fibre, low-emissive glass, reflective glass, plastic materials, additives, paint, plaster, mortar, neoprene	Implemented technologies	Shieldings, heating and cooling, gas system, electrical system, ventilation system, exhaust system, energy supply system, double-skin facade, bow windows, panels, glazed facade, dymanic facade, low-emissive glass, reflecticve glass, laminated glass, windows with integrated sun screens, offests or indentations, thermal insulation, acoustic insulation, natural ventilation, natural lighting, energy facade, double-insulation walls, structural glass facade, radiant floors, prefabricated slabs, false sealing for installations and plants, thermo-acousticallt insulated floor, energy dissipators, stairs, hydraulic lift, freight elevator, catwalks, green roof, sandwich roof	Security and safety systems	Alarm system, domotic system, cameras, sensors, sprinkler, fire resistant walls, escape routes, fire escape stairs, fireproof doors, open spaces, double height spaces, movable and interactive panels, spaces for collectivity on multiple levels

S.W.O.T. Analysis	
Strenghts	**Weaknesses**
Optimal connection with the different points of interest; presence of large open air surfaces overlooking disused sheds; large green spaces; high structures flexibility; presence of areas and laboratories dedicated to cooperation and co-working; central position in the ASI Consortium; view on the main road; low level of degradation of warehouses structures	Location of the site in a marginal area compared to the city center; lack of services in the surroundings; reaching the area only by car and bus; lack of walking and cycling routes; presence of unused railway roads; public transport stops located in non-strategic points; absence of equipped greenery; hydrogeological risk conditions due to the close proximity of the site to the Lama Lamasinata
Opportunities	**Threats**
Creation of new job opportunities; active collaboration between users; possibility of learning about new fields of technology and virtual reality; creating aggregation and meeting spaces; organization of courses and workshops; creation of large green and exhibition spaces; opportunities for amplifying culture and knowledge through smart and digital devices and interfaces; attracting young workers, researchers, start-uppers, creators and developers; development of potentially little-known sectors; promotion of tourism policies and organised visits; organization of entertainment events; broadening of knowledge in the areas of digital and augmented reality; increase of areas dedicated to cultural activities in the urban and industrial periphery	Unused spaces and functions; lack of tourists and users; lack of public funding; little monetary incomes; flood risks; privatisation of the area; unmanageability of green spaces and digital technologies inserted in the museum; high and periodic maintenance of plant components and materials
Risks	
Building vulnerability, inadequate services for population, hazards, poor amenities, increasing of bureaucratic times, construction errors, technical constraints, increasing of construction costs, lack of investments	

Table 4.4.2-6 Building cataloguing sheet (Former Radaelli Sud factory).

4.4.3 The former Divania site

The third case study explained through the MAVT Decision Support System (DSS) concerns the disused factory of the more recent headquarters of Divania SRL. Founded in 1990, the company was active in the artisan production of sofas and armchairs sector. Nowadays, the abandoned complex includes a large warehouse intended for production and goods storage and a smaller building overlooking the main entrance of the lot used as administrative offices (Figures 4.4.3-1; 2).

Figure 4.4.3-1 Former Divania site location in the ASI Consortium area.

From a geographical and logistical level, the former Divania industry is more decentralized from the city core and the residential agglomerations of San Paolo district and Modugno, since it is located in the west part of the Consortium ASI Bari/Modugno developed in the last thirty years. At the same time, the presence a few meters away of the SP54 (Strada Provinciale 54) facilitates the achievement of the questioned site. The site is spread morphologically and architecturally over a narrow and long surface nestled between two lots with smaller sheds. In particular, as can be seen from on-site monitoring activities and through the 2D and 3D design of existing surfaces and volumes (Figures 4.4.3-3; 4), the largest building, designed for the production and processing of sofas, is structurally composed by steel beams with pre-compressed reinforced concrete pillars and englobes an underground floor (13.000 sqm) with a double access ramp and two upper floors of 8182 square meters each.

Figure 4.4.3-2 Former Divania site aerial view (Source: Google Earth Pro).

The modular arrangement of the pillars is repeated throughout the length of the structure and a regular and redundant scan of parallelepiped volumes, connected to each other by the compartments used for vertical connections, fractionalizes and divides the internal areas of the disused production factory into four well-defined spaces. The façade, characterized by an oppressive repetition of glazed openings, prefabricated panels and fireproof stairs, guarantees, at the same time, sufficient aero-illuminating ratios and escape routes. The office building, outdistanced a few meters from the aforementioned structure, is concealed by the size of the production volume. The structure of the management building, also consisting of steel beams and prestressed reinforced concrete pillars, is characterized in plan by segmented and broken perimeter walls that do not incorporate any relevant compositional characteristic.

Figure 4.4.3-3 Existing former Divania site morphology.

According to newspaper articles, the factory, after a first decade of great production and growth, suffered a drop in sales, loss of turnover in the early 2000s and then failed in 2011, completely dismantling the activity. Since this period there have been no proposals to reactivate the site or to redevelop the existing structures leaving in total indifference and carelessness the warehouses and context descripted in a journalistic phrase as "an uncultivated area with disused sheds and abandoned properties without any function, continuing to occupy and consume soil". The area, on the contrary, does not present advanced levels of physical degradation, but only a lack of spaces ordinary maintenance activities and phenomena of widespread humidity in the interiors and on buildings facades.

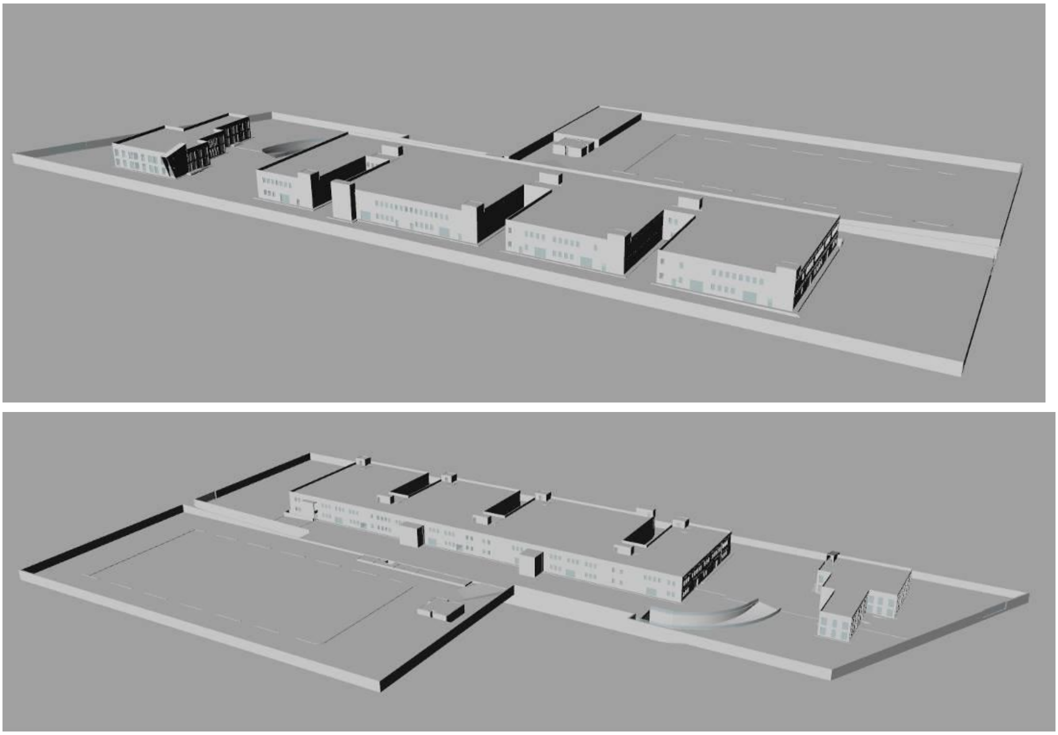


Figure 4.4.3-4 3D model interface of the existing buildings and warehouses included in the former Divania site (Software: AutoCad and Rhinoceros).

Starting from these preliminary considerations, the application of the MAVT approach is implemented with the aim of increasing the useful life cycle of the derelict industrial case study, conferring a new aesthetic identity and functional, flexible and accessible units based on the sector of agriculture 4.0 and modern technologies in the fields of organic and intensive cultivation in greenhouses. In fact, the agricultural, extensive and intensive fruit and vegetable cultivations and wine and olive production sectors drive the economy of the Puglia region. Widely developed in the northern regions, the agriculture 4.0 expresses the set of innovative and sustainable cultivation and agricultural techniques in close connection with remote control systems that exploit renewable resources and manage the water component, controlling the growth of essences in the short term, improving the quality of the finished product and introducing into the market biologic products with intense and well distinguishable tastes. Precision agricultural technologies, which take advantage of the Internet of Things and Big Data Analytics and those related to the Internet of Farming, constitute the modern frontiers of agriculture 4.0. This innovative and contemporary topic, through the cross-analysis of environmental, climatic and crop factors, enables to establish the irrigation and nutritional needs of crops, prevents pathologies, identifies weeds bacteria before their proliferation, carries out targeted meliorative interventions, saves time and resources, affects the quality of products, as well as improves crop yields and working conditions. The enhancement of the Apulian agricultural sector by the functional transformation of disused warehouses into laboratory poles and the implementation of contemporary and avant-garde types of soil cultivation and greenhouses closely affects a large part of the local population. The project purpose analysed for the former Divania factory could unlock important funding from municipal, regional and agricultural consortia that want to introduce effective and sustainable policies of direct training of the farmer, face-to-face laboratory activities of testing products quality and promotion of new management approaches of agricultural land closely linked with smart systems for monitoring the growth and peculiarities of local essences. More specifically, users interested in taking advantage of these services range from the individual serial farmer, to the large local production agricultural companies that want to amplify the knowledge and adopt the modern applications in the agricultural field related to processes automation with the aim of greater land productivity and profitability, achieving green and ecological perspectives.

As described in the previous cases, even for the disused area of the former Divania company the definition of a focus group of 12 experts in the fields of urban planning, architecture, engineering, recovery and passive and home automation technologies provides the identification of three compositional scenarios to rank on the basis of seven judgement parameters (01 economic feasibility; 02 greenery; 03 job opportunity; 04 spaces flexibility; 05 architectural quality; 06 built volumes and 07 spaces accessibility). The three architectural-formal options identified aim to the refurbishment of the pre-existing structures, connecting them with suspended walkways and catwalks to provide a better flows management, incorporating them into a microperforated cover to give compositional unity, increasing the shielding part on the façade and ensuring indoor quality conditions (Figure 4.4.3-5). The outdoor spaces cleared by volumes and superfetations undergo a process of compositional transformation that details each of the options identified by the debate.

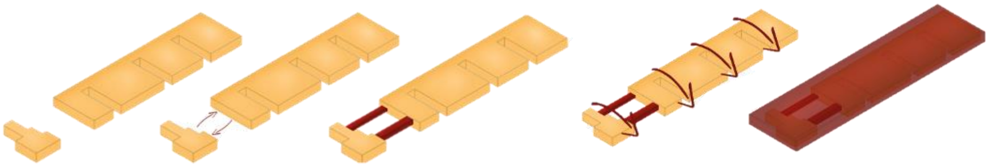


Figure 4.4.3-5 Preliminary former Divania site design solutions.

More specifically, the three interventions considered in the MAVT methodology to estimate the best feasible and sustainable solution to achieve the decision context objective concern respectively (Figure 4.4.3-6):

1) Context characterisation with green fields to create open air agricultural, educational and community spaces. This first scenario does not provide to the insertion of any new volume in the lot and all the accounted functions related to agriculture 4.0 occupy the existing warehouses surfaces;
2) Insertion, in the proximity of the existing sheds structures, of three contemporary envelopes. The second scenario goal consists in increasing the covered available areas to introduce more laboratory and educational services, reducing the agricultural green spaces useful for experimenting contemporary techniques of sustainable extensive cultivation;
3) Particularization of the East and West facades of the main existing shed with intrusive additions of horizontal cantilever volumes to insert didactic rooms and workshops activities and subsequent re-functionalization of outdoor spaces through the insertion of punctual and dismantlable vertical farms for the development of intensive aquaponic cultivation. The removable and non-invasive structures constitute volumetric additions, but, at the same time, do not reduce the soil permeability, being lifted by the ground floor by pilotis.

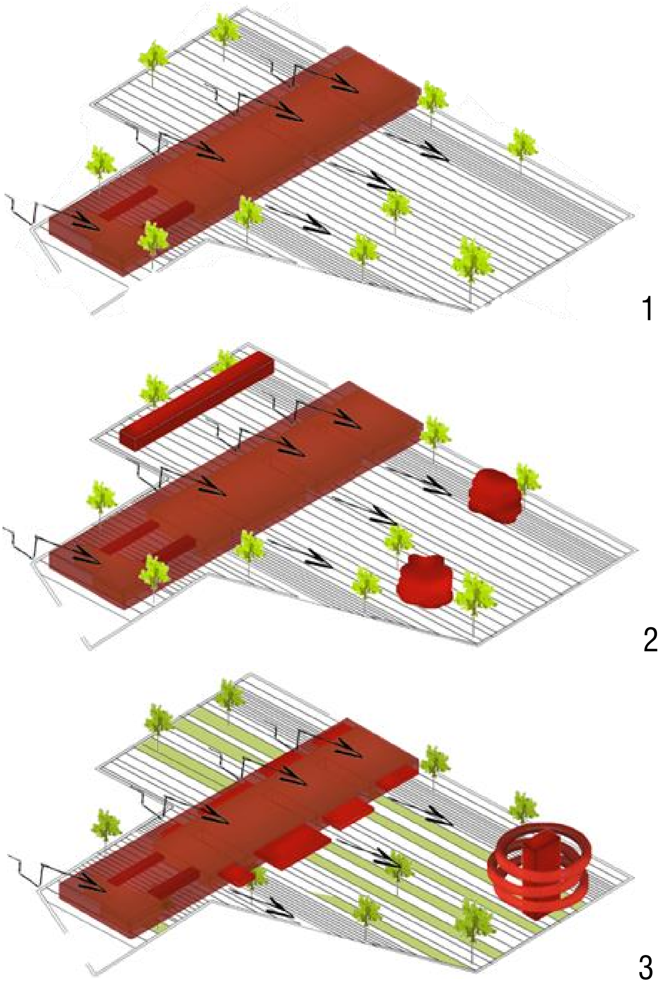


Figure 4.4.3-6 Former Divania site design concepts.

To proceed with the evaluation phase of the three design options, it is necessary to define the individual judgement parameters that emerged from the focus group:

01) Economic feasibility: it consists in the identification of cost factors that affect the feasibility of the single adaptive reuse design option. Four ranges are defined for this qualitative criterion: i) Low, ii) Medium, iii) High, iv) Very high;
02) Greenery: it provides to quantify the permeable surfaces that compose the proposed architectural scenarios. This first quantitative parameter is divided into ten sections ranging from 0-10% to 90-100% and depending on the

greater or lesser presence of green areas in the assumed scenarios (maximum green surface: 52000 m^2 = 100%);

03) Job opportunity: it represents the possibility of introducing functions that increase the available jobs positions in the local territory. This parameter varies from: i) Low, ii) Medium, iii) High, iv) Very high;
04) Spaces flexibility: this criterion can be defined as the possibility of modifying spaces at a functional level, adapting them to the new uses emerged from the debate between experts. Three ranges define this factor: i) Discrete, ii) Good, iii) Very good;
05) Architectural quality: this qualitative attribute evaluates the presence of aesthetically distinctive physical, spatial, compositional, formal and technological components intrinsic in each mentioned design solution. The ranges identified for this criterion vary from: i) Low, ii) Medium, iii) High and iv) Very high;
06) Built volumes: it quantifies the cubic meters added in each selected and analysed compositional hypothesis for the conversion of the decommissioned industrial Divania site. This second quantitative criterion is evaluated considering ranges between 0-10% and 90-100% according to the additions englobed in the individual architectural choices (maximum m^3 of new volumes inserted: 2900 m^3 = 100%);
07) Accessibility: It concerns the possibility of making all the inside and outside services and spaces available and usable by users and people with reduced motor and sensory skills. Four ranges are defined for this qualitative judgement parameter: i) Low, ii) Medium, iii) High, iv) Very high.

Once the design solutions and evaluation criteria useful to classify alternatives have been well framed, the next step consists in the extrapolation and estimation of set of weights. These phases, detailed in the previous sections, are schematised as follows:

a) Definition of raw values of alternatives for all the considered attributes arisen from the expert's face-to-face interactions and summarized in Table 4.4.3-1 (Table 4.4.3-1);

b) Elicitation of value functions, through the conversion of quantitative and qualitative data in numerical ranges, between 0 (worst performance and low objective achievement) and 1 (best performance and high objective achievement), in order to compare non-commeasurable items. The biaxial diagrams measure the impact of the evaluation criteria on the compositional hypotheses identified (Figure 4.4.3-7). Subsequent construction of the first performance matrix by direct comparison of the raw values of alternatives table data with the monotonic trends of value functions (Table 4.4.3-2). The information of the first performance matrix outline that no formal-architectural scenario prevails in all the selected features on the others;
c) Evaluation of parameters using the SWING Weight Method. Twelve experts specialized in multidisciplinary fields of engineering, architecture and urban planning are individually interviewed to estimate the influence of each judgement parameter with respect to the set problem objective, evaluating them separately and independently on the basis of their maximum improvement level. Table 4.4.3-3 (Table 4.4.3-3) contains all the survey responses provided by the 12 actors surveyed according to SWING approach;
d) Calculation of the sets of weights by normalization of responses obtained from the application of the SWING Weight Method and subsequent definition of the second evaluation performance matrix (Table 4.4.3-4). As it is possible to notice from this scheme, all the stakeholders agreed in considering the architectural quality (16.5%) and the spaces flexibility (15.2%) as fundamental issues in the decision problem under evaluation;
e) Formulation of the third performance matrix (Table 4.4.3-5) in which the standardised scores of alternatives and the sets of weights provided by experts are aggregated using the additive assumption to calculate the overall values of the hypothesised adaptive reuse design options. Figure 4.4.3-8 (Figure 4.4.3-8) graphically represents the ranking of alternatives provided by the third evaluation matrix, highlighting the third design scenario as the best alternative according to all the achieved sets of weights.

	01. Ecomonic feasibility	02. Greenery	03. Job opportunity	04. Spaces flexibility	05. Architectural quality	06. Built volumes	07. Accessibility
Scenario 1	Very high	52000 m² (100%)	Low	Very Good	Low	500 m³ (2%)	Very high
Scenario 2	Medium	29400 m² (50%)	Very high	Discrete	High	29000 m³ (100%)	Medium
Scenario 3	High	47500 m² (80%)	High	Good	Very high	2600 m³ (12%)	High

	01. Ecomonic feasibility	02. Greenery	03. Job opportunity	04. Spaces flexibility	05. Architectural quality	06. Built volumes	07. Accessibility
Scenario 1	1	1	0	1	0	1	1
Scenario 2	0.33	0.6	1	0	0.66	0	0.33
Scenario 3	0.66	0.9	0.66	0.5	1	0.9	0.66

	User 1	User 2	User 3	User 4	User 5	User 6	User 7	User 8	User 9	User 10	User 11	User 12
01. Ecomonic feasibility	80	90	50	85	70	80	70	70	90	80	70	80
02. Greenery	100	100	60	90	65	90	75	70	90	80	85	90
03. Job opportunity	100	95	75	90	70	70	70	65	70	85	95	90
04. Spaces flexibility	90	90	90	75	85	80	80	75	80	90	80	75
05. Architectural quality	100	100	100	80	90	100	100	95	90	80	60	80
06. Built volumes	90	80	30	75	40	30	40	30	65	70	60	75
07. Accessibility	95	100	70	80	75	85	50	60	85	80	85	90

	User 1	User 2	User 3	User 4	User 5	User 6	User 7	User 8	User 9	User 10	User 11	User 12	Mean
01. Ecomonic feasibility	0.122	0.137	0.105	0.148	0.141	0.150	0.144	0.151	0.158	0.142	0.131	0.138	0.139
02. Greenery	0.153	0.153	0.126	0.157	0.131	0.168	0.155	0.151	0.158	0.142	0.159	0.155	0.151
03. Job opportunity	0.153	0.145	0.158	0.157	0.141	0.131	0.144	0.140	0.123	0.150	0.178	0.155	0.148
04. Spaces flexibility	0.137	0.137	0.189	0.130	0.172	0.150	0.165	0.161	0.140	0.159	0.150	0.129	0.152
05. Architectural quality	0.153	0.153	0.211	0.139	0.182	0.187	0.206	0.204	0.158	0.142	0.112	0.138	0.165
06. Built volumes	0.137	0.122	0.063	0.130	0.081	0.056	0.082	0.065	0.114	0.124	0.112	0.129	0.101
07. Accessibility	0.145	0.153	0.147	0.139	0.152	0.159	0.103	0.129	0.149	0.142	0.159	0.155	0.144

User 1	User 2	User 3	User 4	User 5	User 6	User 7	User 8	User 9	User 10	User 11	User 12		Mean
0.695	0.702	0.632	0.704	0.677	0.682	0.649	0.656	0.719	0.708	0.710	0.707	Scenario 1	0.687
0.433	0.433	0.456	0.437	0.437	0.457	0.455	0.457	0.423	0.422	0.443	0.436	Scenario 2	0.441
0.760	0.756	0.747	0.755	0.745	0.753	0.761	0.755	0.756	0.746	0.739	0.754	Scenario 3	0.752

Tables 4.4.3-1; 2; 3; 4; 5 Raw values table; Standardised scores of alternatives; Experts questionnaire answers; Sets of weights provided by the experts; Overall values of scenarios.

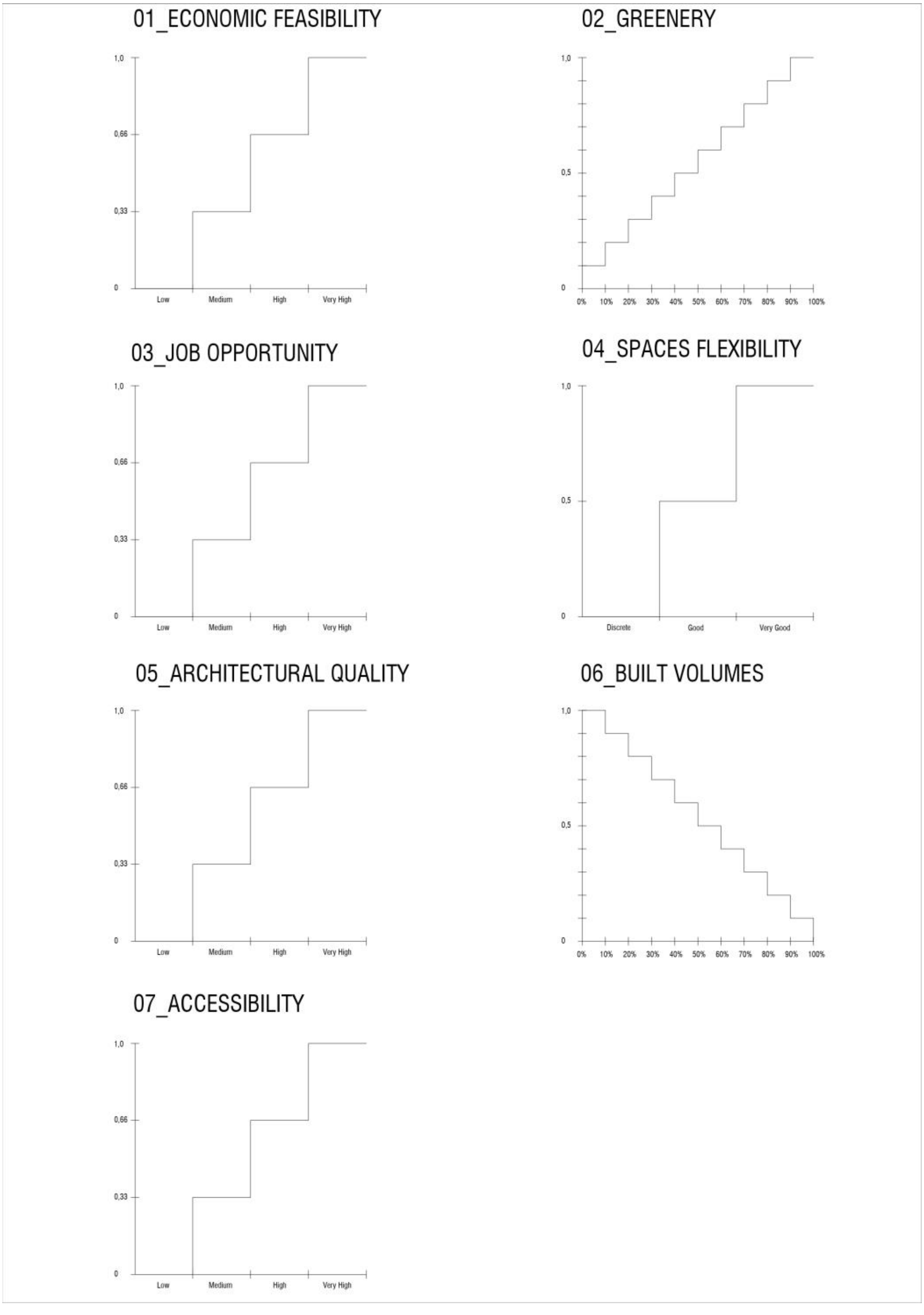


Figure 4.4.1-7 Former Divania site elicitation of value functions for each attribute.

The master plan related to the design proposal selected by the MCDMA is shown in Figure 4.4.3-9 (Figure 4.4.3-9). In addition, all the information about the physical, technological, social and functional characteristics of the existing industrial site asset and adaptive reuse hypothesis outlined by the application of MAVT and SWING Weight Method are enclosed in the building cataloguing sheet (Table 4.4.3-6). This classification table helps stakeholder's decision in complex planning contexts, providing a general framework of the input features to introduce in the DCS multicriteria structure for the calculation of the feasibility coefficient (f) and the risk entity score (r).

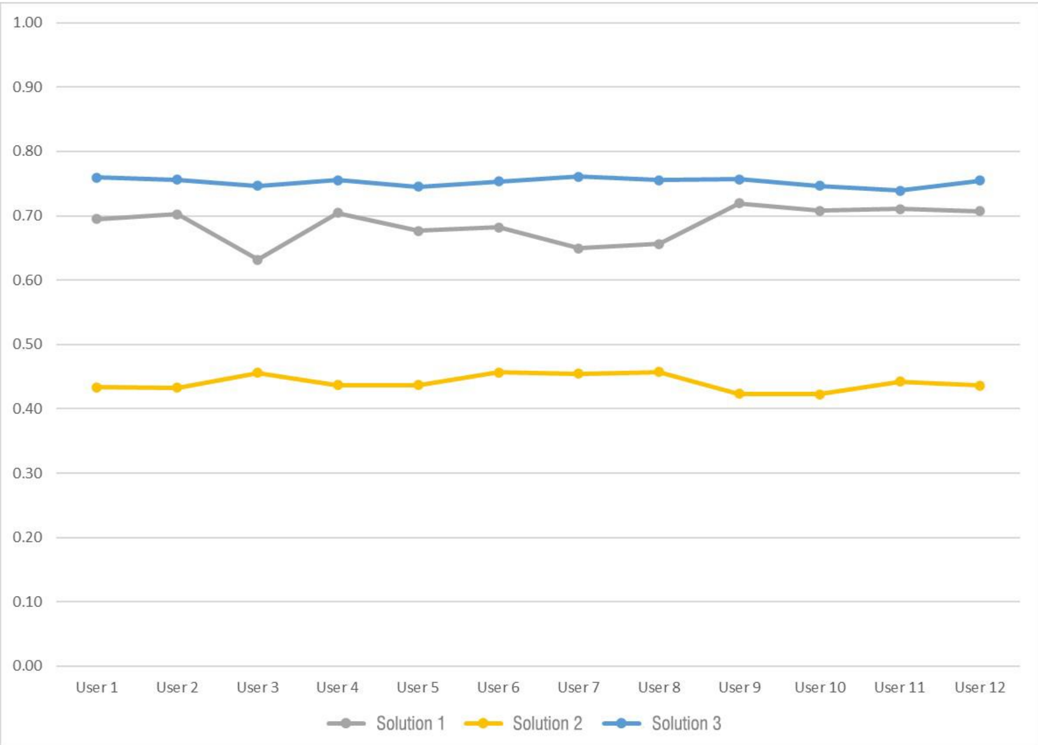


Figure 4.4.3-8 Ranking of the design alternatives for each user involved.

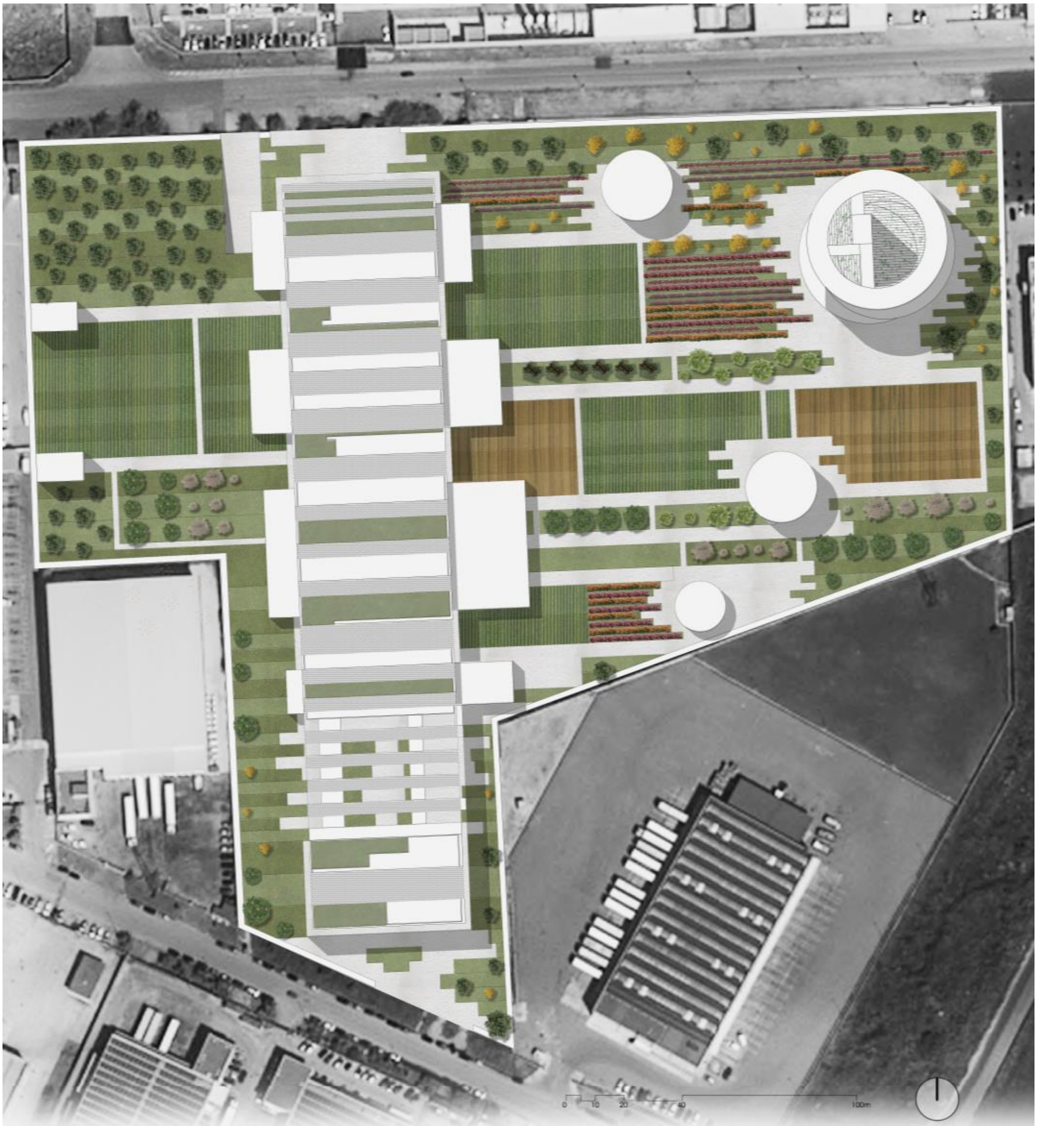


Figure 4.4.3-9 Design proposal of the selected architectural alternative for the conversion of the former Divania site (Authors: Zappimpulso V. and Vizzarri C.).

General Data			
Building/site name	Former Divania factory	Climatic zone	C
City	Modugno	Orientation	East - West
Region	Puglia	Number of entrances	2
Nation	Italy	Landscape quality	*Low*
Address	Gladioli Street, 19-21, 70026, Modugno BA, ASI Consortium	Building Size	*Medium*
Site location	41°06'06.4"N 16°45'40.7"E	Site surface (m²)	68.765
Years of construction and dismission	1990/2011	Building surface (m²)	9.182
Distance from city center	12Km (20 min)	Total volume (m³)	91.820
Number of existing buildings	2	Level of maintainablity	Site =*high*
Number of historic buildings	0		Context =*medium*
Building structural typology	Prefabricated frame structure in prestressed reinforced concrete		Infrastructures =*medium*
Green areas (m²)	31.900	Reclamation interventions	*No*
Public space (m²)	27.683	Glazed surface	*Medium*

Existing buildings data					
Building Surfaces (m²)	Building 1	8182	Volumes (m³)	Building 1	81411
	Building 2	1000		Building 2	8550
Heights (m)	Building 1	9.95	Number of floors	Building 1	3
	Building 2	8.55		Building 2	2

Physical analysis – Existing abandoned industrial site					
Level of decay	Site	*low*	Dampness	*medium*	Presence of constraints
	Buildings	*low*	Pests	*low*	
	Materials	*medium*	Natural attack	*medium*	Public spaces almost non-existent; Absence of well-kept green spaces; Non-existent connection between buildings; High distance from the city center.
	Structures	Pillars =*low*	Existing plants	Electric system	
		Beams =*medium*		Water and exhaust system	
		Walls =*low*		Heating and cooling	
		Vertical connections =*low*		Fire-fighting system	
		Foundation =*low*	Site conditions	Soil type	Consolidated
		Floor =*low*		Presence of vegetation	*medium*
		Roof =*medium*		Level of traffic	Car =*medium*
		Joints =*medium*			Bike =*low*
		Facade =*medium*			Bus =*low*
	Plants	*medium*			Camion =*medium*
	Technologies	*low*			Train =*low*
	Functional decay	Parking areas =*low*			Pedestrian =*low*
		Space dimensions =*low*			Other ….
		Flows management =*low*		Level of pollution	Environmental=*medium*
	Green areas	*medium*			Acoustic=*medium*
	Context	*low*			Water=*low*
Level of humidity	*medium*				Soil=*medium*
Presence of asbestos	*none*				Light=*low*
Lack of building parts	*none*				Air=*high*

Project					
Buildign transformation interventions	Cladding	*Yes*		Subtraction	*No*
	Interior design	*Yes*		Demolition	*No*
	Addition	Connection	*Yes*	Envolve	*Yes*
		Merge	*No*	Outside	*Yes*
		Elevation	*No*	Connection through public space	*Yes*
		Intrusion	*Yes*	Landscape and urban art	*Yes*
		Stack	*No*		
		Duplication	*No*	Excavation	*No*
N. of new buildings	6		M² added surfaces	3.219	
N. of refurbished buildings	2		M³ added volumes	41.796	
N. of demolished buildings	0		Insertion of new openings	*Yes*	

New buildings project data					
Building Surfaces (m²)	Building 1	160	Volumes (m³)	Building 1	1600
	Building 2	160		Building 2	1600
	Building 3	482		Building 3	4820
	Building 4	482		Building 4	4820
	Building 5	245		Building 5	1225
	Building 6	1160		Building 6	23200
Heights (m)	Building 1	10	Number of floors	Building 1	3
	Building 2	10		Building 2	3
	Building 3	10		Building 3	3
	Building 4	10		Building 4	3
	Building 5	5		Building 5	1
	Building 6	20		Building 6	7
Functional analysis			**Social analysis**		
Space flexibility and convertibility	*high*	*high*	Stakeholders involved	Project manager, facility manager, site manager, consultants, inventors, architects, engineers, developers, graphic designer, construction team, workers, agronomists, technicians, academic experts, surveyors, landscapers, pollution manager, Public administrations, Municipal Council, Regional Council, professors, promoters, investors.	
Main functions	Function category	Specific function			
	Cultural	Conference center, university lab, biocenter, science laboratories, research center			
	Commercial	Bar, vertical farm, greenhouses, retail			
	Offices	Hubs, smart office, storage, garage			
	Education	Workshop, educational farm			
	Public spaces	Park, garden, square, meeting rooms			
	Spaces for healthcare	Analysis center			
N. of services	20				
Level of accessibility and connectivity	*high*	*medium*			
Spatial flow management	*medium*		Users	Community, public associations, neighbors, professors, agronomists, employees, students, workers.	
Dismantlability	*medium*				
Project building total surface (m²)	16.000				
Project green areas (m²)	47.276				
Project public spaces (m²)	6.534		Population needs	Increase of public spaces, increase of services, increase of green spaces, job opportunities, increase district security and safety.	
Distance from points of interest	Points of interest	Distance (Km)			
	Saint Nicolas church	14.3			
	Pane e pomodoro beach	26.3			
	S. Girolamo beach	9			
	San Nicola stadium	10.8			
	Team theater	11.9			
	Polytechnic of Bari	17.5			
	Aldo Moro University	11.1	Site importance for society	*medium*	
	Airport	5.6	Usability and liveability	*high*	
Building connectivity	Points of interest	*low*	Site aesthetic identity	*medium*	
	Parking areas, public spaces and green areas	*low*	Site attractiveness	*medium*	
	City centre	*low*	Relation society-environment-building	*high*	
	Waterfront	*medium*	Social inclusion	*medium*	
	Main services	*medium*	Social participation	*high*	
Other information					
Economic feasibility	*high*	Political feasibility	*high*	Investments	*medium and public*
Applied materials	Gravel, sand, expanded clay, clay, recycled metal, iron, steel, aluminium, concrete, lightweight concrete, fiber-reinforced concrete, gres, granite, rock wool, glass wool, glass, thermochromic glass, plastic materials, self-cleaning paint, neoprene, plaster, mortar, vacuum insulation panels	Implemented technologies	Water management, shieldings, photovoltaic system, heating and cooling, electrical system, ventilation system, exhaust system, energy supply system, double-skin facade, bow windows, panels, green facade, thermochromic glass, laminated glass, vertical brise soleil, microperforated metal, offsets, thermal insulation, acoustic insulation, natural ventilation, natural lighting, bioclimatic facade, structural glass facade, double insulation walls, radiant floor, false sealing for installation, earthquake resistant foundation, seismic dissipators, stairs, lifts, freight elevator, catwalks, sandwich roof, photovoltaic roof	Security and safety systems	Alarm system, domotic system, cameras, sensors, fire resistant walls, sprinklers, fire escape stairs,escape routes, fireproof doors, open spaces, spaces for collectivity on multiple levels

S.W.O.T. Analysis	
Strenghts	**Weaknesses**
High flexibility of existing spaces to host new functions; presence of poorly degraded sheds; regular and modular composition of structures; proximity of the lot to the main connecting road arteries; presence of new urban and road infrastructure	Moderate distance from main services; public transport services do not exist; lack of slow mobility lanes; high distance from the city centre; little maintenance of the areas adjacent to and inside the production site; lack of urban green areas and public spaces for the community; decentralisation of the site from the city centre; possibility to reach the disused lot only by vehicles; high density of the built in the abandoned lot compared to the free areas to be dedicated for public spaces and gardens
Opportunities	**Threats**
Inclusion of laboratory and scientific functions for the development of research in the agricultural and agri-food field; presence of green spaces that act as a lung in the industrial area; assistance to farmers; quality assessment of local cultivated products; presence of rest areas and large road link arteries; cataloguing local products and achievement of certifications to protect and provide food quality; monitoring of product growth phases; increased controls and analyses on agricultural products; study and discovery of new pathologies and new treatments; promotion of agriculture 4.0 combined with technology to improve crop yield and quality; use of new technologies for cultivation in greenhouses and vertical farms; study and creation in the laboratory of new products with better properties; implementation of new cultivation methods and natural fertilizers; bringing the population closer to the use of biologic and km0 products; organization of courses and workshops for farmers on new cultivation techniques; new job opportunities	Future shortage of skilled labour; persistence of low national commitment in agricultural research and innovation; poor attractiveness of the sector for young workers; risk that small companies may be absorbed by large multinationals; possible lack of funds for research; competitiveness of local businesses; unusability of services as they are far and isolated from the urban center
Risks	
Spatial constraints, inadequate services for population, poor amenities, technical constraints, building disuse by users, incompatibility of the expected functions towards the actual population needs	

Table 4.4.3-6 Building cataloguing sheet (Former Divania site).

4.5 Application of MCDMA for the selection of adaptive reuse scenarios on other decommissioned heritage industrial sites

Decision Support Systems (DSSs) are also applied to evaluate the best adaptive reuse conversion scenario of disused heritage industrial sites outside the actual productive area of Bari. In particular, the ASI Bari/Modugno Consortium borders to the east a popular district that for two thirds of its extension is occupied by two wide historical disused industrial plants: the STANIC Refinery and the ENEL Power Plant. The main goal of this section of the research concerns the possibility of extending adaptive reuse policies outside the borders of the ASI Consortium, considering other latent resources to be renewed and re-functionalized to fill the urban voids of the suburbs of the Apulian capital. In addition, the two examples considered incorporate different architectural and spatial components, but with morphological-constructive connotations dating back to the war and post-war period. At the same time, the analysis of the conversion, regeneration and re-functionalization design solutions, using adaptive reuse models, of the two case studies of industrial archaeology is more complex than the examples treated previously, since multiple factors come into play. They must be evaluated not only from the physical and spatial aspects of the existing, but also selecting the option that most preserve the iconic historical and architectural features within the industrial context. Moreover, the preliminary study of the existing structure of disused places allows to merge and strengthen the connections between the architectural singularities of the past that preserve the historical-evolutionary memory of the production sector in the city of Bari and the new technological and formal solutions introduced to guarantee high standards of liveability and accessibility of the reused existing spaces and volumes. To achieve these ambitious objectives, this part of the research adopts two different decision-making approaches for the selection of the most feasible and efficient alternatives of building adaptation, and respectively:

A) The Multi-Attribute Value Theory (MAVT) (Fishburn, 1967; Raiffa, 1969; Keeney & Raiffa, 1976; Ferretti et al., 2014) for the definition of the functional solution that most reflects the intrinsic characteristics and the extension of the Former STANIC Refinery areas, redeveloping this abandoned heritage industrial context in a large educational and cultural green lung strictly linked with the Lama Lamasinata park and that combines the decentralized peri-urban and marginal fabrics with the consolidated city tissues. The innovativeness of the decision support methodology applied to the case study lies in the identification and comparison of many choice factors for the structuring of the three performance matrices to classify the hypothesized functional alternatives (Vizzarri et al., 2020b). In addition, the evaluation of judgement parameters by the focus group experts is not carried out through the SWING Weight Method, but with online interviews and teams chat;

B) The Optimised Analytic Hierarchy Process (O-AHP) (Sangiorgio, 2018; Sangiorgio et al., 2018a; 2018b) is instead applied to evaluate, on the basis of a of multiple selection parameters (more than eight criteria), which of six different design and functional scenarios for the regeneration of the former ENEL power plant preserves the architectural and historical components present on the site and introduces interesting policies of sustainable development of the STANIC district. In addition, the multicriteria selection approach is being adopted for the first time to assess the adaptive reuse potentials of a disused historical industrial context. The peculiarity of this modern and interesting decision support methodology is due to the consistency and robustness of the system in managing and quantifying the incidence of independent evaluation attributes and sub-attributes in the preliminary selection and monitoring processes of building refurbishment and adaptation design alternatives in complex decision contexts.

4.5.1 The former STANIC Refinery

The former STANIC Refinery has been considered a symbol of Bari industrial past for over fifty years. The conversion of this vast empty area is at the basis of the local debate concerning the recovery of unused industrial sites in the city of Bari and their importance for the development of smart and sustainable planning and regeneration policies. This area is grafted between the natural landscape of the Lama Lamasinata and buildings seriality of the ASI Consortium of Bari/Modugno. The site of the former refinery covers about 530.000 sqm, approximately 3.7 km perimeter, and is located within the homonymous district (Figures 4.5.1-1; 2).

Figure 4.5.1-1 Former STANIC Refinery location.

From the information acquired about the architectural and morphological evolution of the refinery, the industrial site has undergone many transformations over time that have gradually modified the composition of its spaces. Nowadays, after the dismantling and repeated remediation of the site (1999-2010), only a few warehouses remain, preserving the historic character of the refinery. Built in 1937, the STANIC industrial complex began operating in 1938. Over the years, the analysed dismissed context has undergone significant expansions, due to the growth in demand, the increase in processing and the subsequent differentiation of processes. In particular, from 1947 to 1967, new tanks and infrastructures were added, achieving the possibility of developing new fuels.

Figure 4.5.1-2 Former STANIC Refinery aerial view (Source: Google Earth Pro).

The refinery ended the production activity in 1974. In the following years, it assumed the function of coastal storage until the 1990s. After the disposal of the cisterns, which took place in 2002, and the subsequent reclamation of the entire context, lasted until 2010, the situation has remained unchanged within the area up to the present day. The high level of degradation of the Lama Lamasinata, the environmental, acoustic and air pollution and the proximity to a vast productive not attractive area promote the growing tendency of the STANIC refinery to remain unused and to make it less prone to be subjected to new transformations. The refurbishment of abandoned or disused industrial buildings is a difficult process to manage, since it is characterized, in most cases, by problems related to site pollution and consequences for future generations in terms of health and economic commitments. The remediation of these areas entails a significant increase in costs for the realization of the conversion project. At the same time, the reuse of these latent resources becomes an opportunity to transform the city, create new possibilities and change the quality of the surrounding urban fabric. This concept is strengthened considering the environmental and landscape aspects as another key elements to be incorporated into the building design and urban regeneration processes. The aim of this section consists in the promotion and ranking of sustainable solutions for the refurbishment, protection and re-naturalization of the abandoned factory, hypothesising an ecological urban system through the insertion of green spaces and public cultural and didactic infrastructures strictly interconnected to each other and with the surrounding districts. This study doesn't exclude the extreme proximity of the Lama Lamasinata to the former Stanic site. However, over the years, the high district degradation, the transformations of the urban fabric by human and pollution caused by the presence of illegal landfills have defaced the natural landscape. Urban interventions and improper uses have progressively triggered processes of reduction and fragmentation of the herbaceous, shrub and arboreal cover of erosive furrows so much that in some cases spontaneous vegetation is presented in residual form. Considering physical-morphologic aspects, the refinery contained hundreds of structures including buildings, warehouses, service rooms and tanks. Today only a few sheds envelopes remain in the refinery site. Documents and on-site analyses identify 18 volumes in the STANIC industrial site. Eight of these are near the historic entrance of the refinery, two are tanks and eight are other buildings for storage use scattered in the abandoned area (Figure 4.5.1-3).

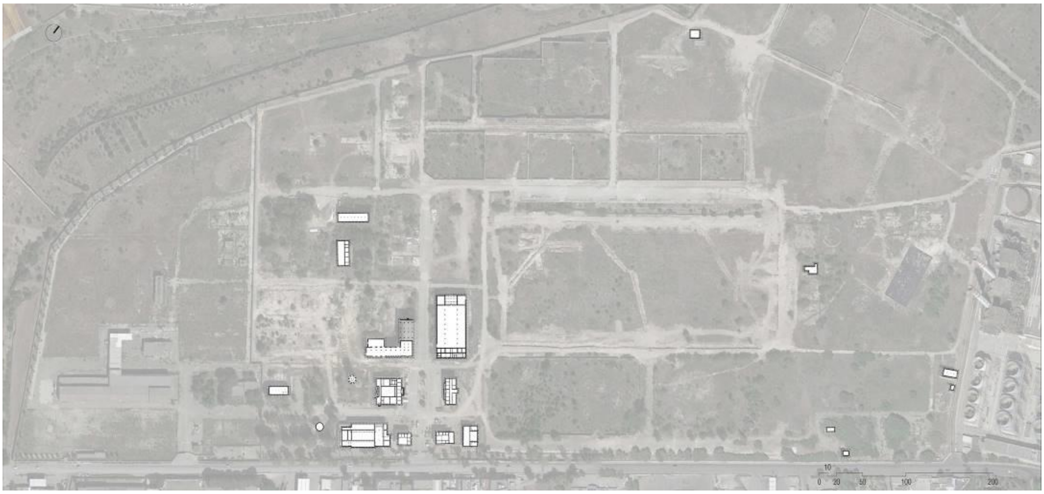


Figure 4.5.1-3 Existing STANIC Refinery warehouses.

The most relevant industrial heritage and historic buildings are those facing the main avenue, of which there are still evident traces. In particular, six warehouses structures have been surveyed and contemplate to understand the possible functional scenarios to insert in this wide brownfield. The existing sheds are composed by reinforced concrete bearing structures, trusses and double height spaces.
The connection of the area with the city consists mainly of urban roads for transports, while alternative routes of soft mobility are completely absent. The main entrance to the area overlooks the urban road of Via Bruno Buozzi, which connects the area to the F. Crispi Metro station and the F. Crispi railway station, until the waterfront. Via Bruno Buozzi represents one of the most important crossing axes of the city. This principal road ensures the connection of the site to the nearby routes SS96 and SS16. Another important urban street of the quartier is Viale Europa, which runs alongside the adjacent ENEL electric power station. This second route connects the city to the San Paolo peripheral district, crossing the Lama Lamasinata (Figure 4.5.1-4). Inside the former industrial area, it is still possible to see the remains of the internal viability of the refinery, characterized by a cardo-decuman structure and a series of orthogonal paths. The internal infrastructure system identifies strong links with the city and the presence of old railway paths. Although the area appears distant and difficult to reach, with an adequate connection to the main polarities it can absolutely be integrated with the rest of the main attractions, developing a unique landscape scenario. In addition, slow mobility, especially cycle pathways, could become a fundamental resource for the use of this abandoned area.
The area around the Lama Lamasinata and former STANIC Refinery appears strongly fragmented and isolated from the rest of the city. The landscape and the entire periphery of San Girolamo, San Paolo and Stanic districts present high level of degradation and obsolescence due to the absence of connections and structures capable of catalysing attention in this marginal district. The former services, after the refinery divestment, gradually closed or moved to other parts of the city, bringing the district to the current degraded and isolated situation. A few services are located near the social housing residential complex, where it is possible to find a nursery school, a post of-

fice, an elementary school, a pharmacy, and some other small shops for necessities. There are no cultural or sports polarities, in the absence of which the residents are forced to travel by car to reach places in the city with more services.

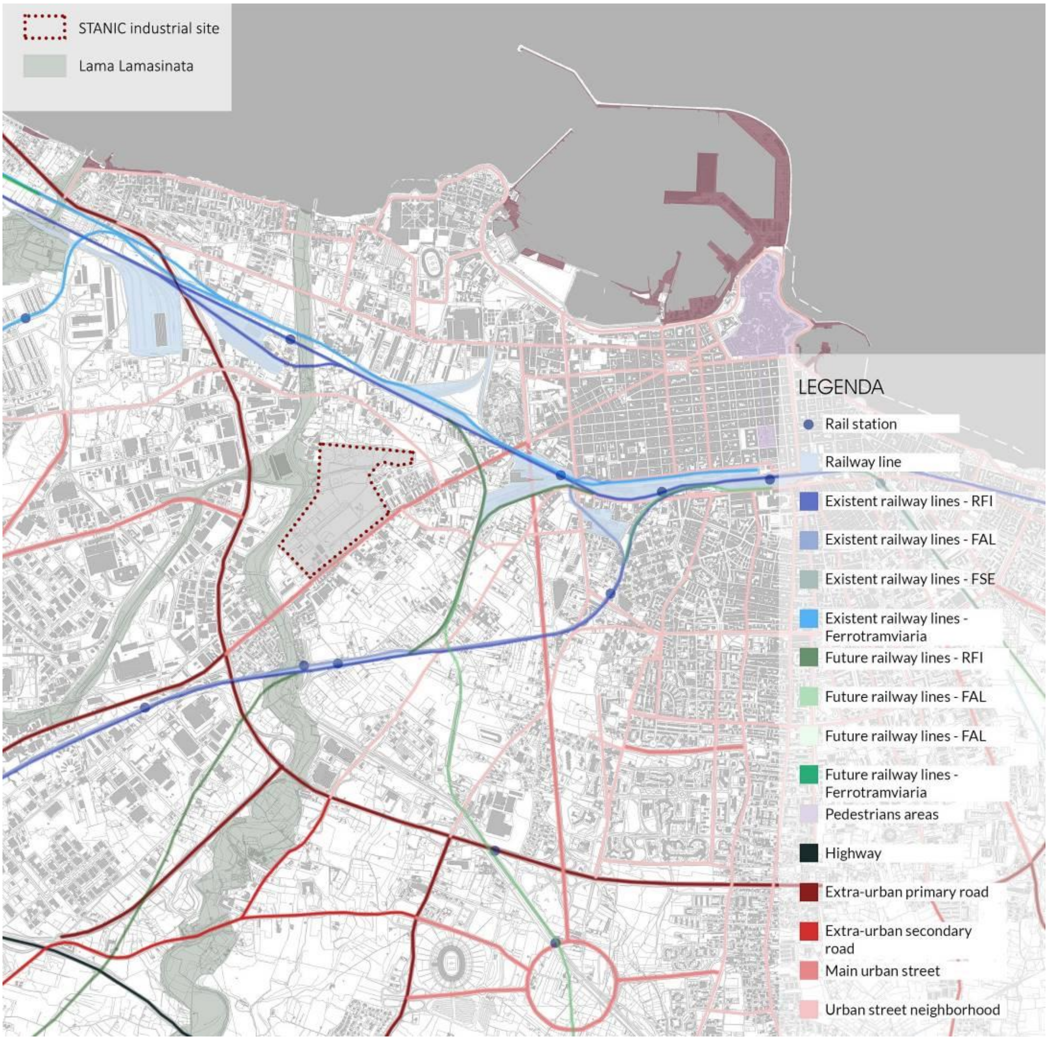


Figure 4.5.1-4 Urban analysis map.

Once the physical, environmental, functional and social features characterising the former STANIC Refinery have been framed, the next step involves the implementation of the MAVT's decision-making approach for the evaluation and classification of adaptive reuse design alternatives that can effectively modify the attractiveness of the places and meet the primary needs of the local population. The creation of a focus group with twenty-one stakeholders specialized in the construction, restoration and environmental-historical-architectural preservation fields, activates discussion processes about the selection of functional reuse scenarios and judgement parameters. In particular, three different and innovative functional solutions and 22 evaluation criteria are arisen from the debate.

The adaptive reuse interventions identified differ not only considering the relationship between built and natural landscape, but also in their type of use (public, semi-public and private). Each option includes services strictly related to the population needs and to the urban shape. The three scenarios are listed as follows:

a) Environmental and thematic park: the proposal focuses on recycling the buildings, production structures, machinery, and even the grounds themselves. Through bio-phytoremediation techniques, the soil and water would be "cleaned and greened". The preservation and adaptation of the existing structures allow to safeguard the historical memory of the place. The recovered buildings are used as incubators to host recreational functions and community services that frame the park not only as a large green walking lung, but also as a place to perform outdoor activities, sports, creative and educational workshops;
b) Technological, cultural and education park: the concept is to create a large urban park that partially tends to reconnect the existing urban fabric through the insertion of ecological corridors. This expedient stimulates and favourites sustainable urban mobility and people flows, supported by the presence of an interchange hub. The role and naturalness of the Lama Lamasinata is restored, making it an integral part of the new system. Remediation and bio-phytoremediation activities are two techniques that become even more fundamental today in an environmentally damaged area. Classrooms, offices, space to study different plant species, educational and hemp production la-

boratories, archives, areas for the transformation and packaging of products and zero-km markets compose the functional program;

c) Manufacturing and industrial park: this functional typology restores the pre-existences and increases the density of the buildings with the aim of introducing functions relating to the manufacturing and craft field. It is conceived as an innovation accelerator for all companies that aim to enlarge their market with eco-efficient solutions. The naturalistic-environmental aspect is always present in order not to damage the landscape quality of the place, prevailing a purely private use of the site. Start-ups, incubators, spin-offs, warehouses, smart offices and design, production and assembly laboratories occupy most of the area of the former STANIC Refinery.

To advance with the ranking process of the three alternative, it is necessary to define the individual judgement parameters, extrapolate the raw values table of factors arisen by the focus group debate and formulate the monotonic functions diagrams for converting data qualitative sets in numerical values. More specifically, starting from the main design fields explained in the first part (Social, Physical, Environmental and Urban features) of the section outlining strengths and constrains of the case study, the major factors that affect decisions according to the optimal design solution for the former STANIC factory have been identified. The selected criteria are listed as follows:

1. Social parameters (8)
   a) Job opportunity: this first indicator analyses the quantity and quality of job that the new destination offers;
   b) Public spaces and green areas: it measures the quantity and quality of the present meeting places, parks and gardens. Green areas and public spaces can be considered as places of aggregation, socialization and inclusion. They represent the components to eradicate inhabitants and visitors iterations;
   c) Pedestrians areas and slow mobility: the presence of permeable and walkable roads ensures to improve the socialization and use of public land by visitors

and residents. The amount of slow mobility routes and public spaces guarantee the development of society and urban asset;

d) Services: this scope outlines the quantity, differentiation and quality of functions that can promote the Stanic district as a stable, sustainable, smart and self-sufficient city context. It allows to increase the wealth of its inhabitants and thus to improve their living conditions;
e) Social activities: increasing of the satisfaction of the inhabitants and quality of life. This parameter evaluates the presence of activities to create neighbourhood relationships and social inclusion;
f) Attractiveness: the ability of an area to attract and manage different flows of people due to its activities or infrastructures;
g) Connection with the city centre: the analysis of the times and methods of moving not only between the services and places within the project area but also with the rest of the city outlines and traces the best connection routes to the various metropolitan services and points of interest;
h) Gentrification: the insertion of new services and fast public mobility increases the quality of life and re-evaluates district role in the city urban structure.

2. Physical - Morphologic parameters (4)
   i) Recovery of the historic-architectural pre-existences: it studies buildings and works of considerable architectural or artistic interest, in order to assess the best strategy for their conservation and restoration;
   j) Compatibility of the intervention with the context: the analysis of the present built resources ensures to structure feasible intervention strategies without dominating or designing elements in contrast with the pre-existences;
   k) Introduction of new volumes: the possibility to introduce new volumes in the existent site morphology, considering current regulations in the field of restoration, construction and urban planning;
   l) Maintainability: this criterion considers the feasibility of maintenance activities on an historical building.

3. Environmental parameters (5)
    m) Landscape quality: it measures the natural potential of the place and its values in terms of greenery and environmental attractiveness;
    n) Presence of green areas: the amount of green areas is not only important in social or landscape terms. Green areas trigger an increase in biodiversity, a better quality of air and water, having consequences on the quality of life of the inhabitants;
    o) Safeguard of the natural native species: this attribute highlights the ability to enhance and conserve native species and biodiversity, making users aware of the conservation and respect of local species;
    p) Site renaturation and remediation: this parameter evaluates the level of pollution and degradation of the area;
    q) Compatibility of the new natural species with the local context: it measures the level of integration of the planned green areas with pre-existing species, without compromising the context morphology and landscape.

4. Urban parameters (5)
    r) Iconicity: it consists in the ability of a place to be identified as a reference point for the city;
    s) Space flexibility: the analysis of space flexibility is a fundamental prerogative for the architecture of reuse. The more flexible a space, the more it can adapt to as many functions as possible;
    t) Usability: the ability of an object to be used totally in tranquility and without major hitches by as many people as possible;
    u) Flow management: it explains how, at urban level, the connections between the place and the city joints can be integrated and improved;
    v) Accessibility: this attribute includes the characteristics of a place to be reached easily and in total safety, to be crossed with different transportation systems and by different kinds of people, with specific needs and objectives.

Table 4.5.1-1 (Table 4.5.1-1) provides the raw scores of functional options according to all the considered attributed identified in the focus group discussion.

Attributes	Sub-attributes	Environmental and thematic park	Technological, cultural and education park	Manufacturing and industrial park
Social analysis parameters	Job opportunity	L	VH	VH
	Insertion of public spaces and green areas	TS	TS	PS
	Insertion of pedestrians areas and slow mobility	TS	TS	PS
	Introduction of new services	PS	TS	TS
	Social activities	H	VH	M
	Attractiveness	H	VH	M
	Connection with the city centre	PS	TS	TS
	Gentrification	M	H	H
Physical - Morphologic analysis parameters	Recovery of the historic and architectural pre-existences	TS	TS	TS
	Compatibility of the intervention with the context	H	H	H
	Introduction of new volumes	VL	L	M
	Maintainability	L	M	M
Environmental analysis parameters	Landscape quality	VH	VH	M
	Presence of green areas	VH	H	M
	Safeguard of the natural native species	TS	TS	PS
	Site renaturation and remediation	M	M	H
	Compatibility of the new natural species with the natural context	VH	H	L
Urban analysis parameters	Iconicity	M	H	VH
	Space flexibility	VH	VH	VH
	Usability	VH	VH	VH
	Flow management	H	H	H
	Accessibility	VH	VH	VH

Table 4.5.1-1 Raw values of alternatives table (VL=Very Low, L=Low, M=Medium, H=High, VH=Very High; NS=Not Satisfied, PS=Partially Satisfied, TS=Totally Satisfied).

The next step consists in the elicitation of the value functions, which display mathematical diagrams representing human judgements. In particular, for the description of all the identified parameters, only three different qualitative graphs are formulated.

These schemes allow to classify sub-criteria between 0 and 1, defining options performances with respect to the achievement of the decision goal (Figure 4.5.1-5).

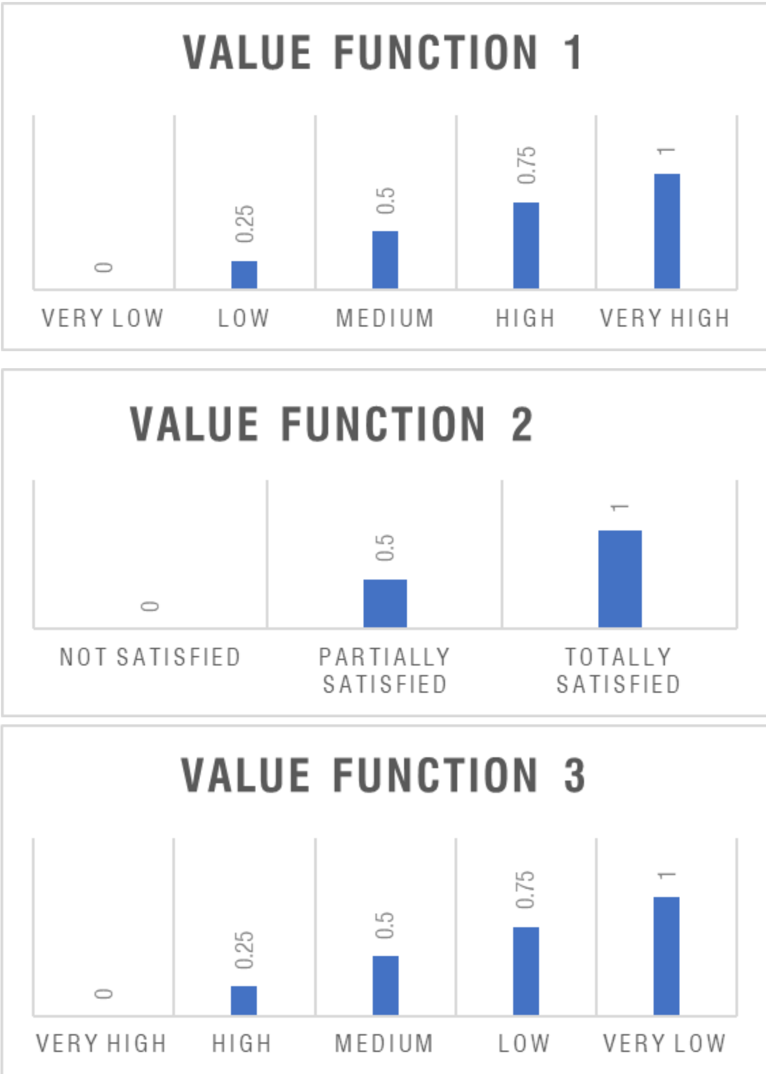


Figure 4.5.1-5 Elicitation of value functions for each attribute.

As the result of the value function elicitation procedure, the first performance matrix of standardized scores of functional adaptive reuse alternatives under consideration is designed. In addition, Table 4.5.1-2 (Table 4.5.1-2) underlines that there isn't any dominant scenario on all the accounted judgement parameters.

Attributes	Sub-attributes	Environmental and thematic park	Technological, cultural and education park	Manufacturing and industrial park
Social analysis parameters	Job opportunity	0.25	1	1
	Insertion of public spaces and green areas	1	1	0.5
	Insertion of pedestrians areas and slow mobility	1	1	0.5
	Introduction of new services	0.5	1	1
	Social activities	0.75	1	0.5
	Attractiveness	0.75	1	0.5
	Connection with the city centre	0.5	1	1
	Gentrification	0.5	0.75	0.75
Physical - Morphologic analysis parameters	Recovery of the historic and architectural pre-existences	1	1	1
	Compatibility of the intervention with the context	0.75	0.75	0.75
	Introduction of new volumes	1	0.75	0.5
	Maintainability	0.75	0.5	0.5
Environmental analysis parameters	Landscape quality	1	1	0.5
	Presence of green areas	1	0.75	0.5
	Safeguard of the natural native species	1	1	0.5
	Site renaturation and remediation	0.5	0.5	0.25
	Compatibility of the new natural species with the natural context	1	0.75	0.25
Urban analysis parameters	Iconicity	0.5	0.75	1
	Space flexibility	1	1	1
	Usability	1	1	1
	Flow management	0.75	0.75	0.75
	Accessibility	1	1	1

Table 4.5.1-2 Standardised scores of alternatives.

Once the alternatives have been evaluated through value functions ranges, it is necessary to define the attributes weights of the decision problem. Twenty-one different experts in the context of urban planning, history of architecture, cultural heritage and refurbishment have compiled a well-structured online questionnaire to estimate the pa-

rameters that most affect the composition and design choices of building conversion in the preliminary design stage. The survey, therefore, is based on the ranking, in a range from 1 (very unimportant) to 5 (very important), of the categories and parameters identified from the expert's debate. The results, extrapolated by the means of stakeholders' answers, show that most of the criteria are fundamental for the activation of urban regeneration policies for abandoned industrial sites. However, especially for sites with architectural importance, a parameter to be considered is the recovery of pre-existences with the aim of safeguarding the historical memory of the place. Even the environmental aspects are not to be overlooked, especially when intervening on polluted industrial areas which require soil remediations. The parameters, relating to site attractiveness, flexibility of spaces and usability features, are also relevant. Table 4.5.1-3 (Table 4.5.1-3) contains all the weights related to each criterion and normalized according to the category they belong to. These considerations are reflected in the weight of the four main categories, where the most important attribute concerns the urban features (25,59%), followed respectively by the environmental (25,29%), social (25%) and physical - morphologic (24,12%) topics.
In the last methodology phase, each attribute score extrapolated by the value functions is compared with the corresponding weight, arisings by the focus group survey. In addition, the estimation and normalization of parameters percentages allow to calculate the total adaptive reuse feasibility score of the three alternatives.
To simplify the calculation of the third performance matrix of the MAVT approach in the case of a large number of judgment parameters greater than 8, the additive model is implemented to interpolate the normalized weight of each parameter obtained from the average values of the experts interviewed with the standardised scores of the alternative obtained from the value functions.
On the right side of Table 4.5.1-3 (Table 4.5.1-3) the partial and overall values and the rankings of the design solutions are calculated. This multicriteria evaluation methodology illustrates that the technological, cultural and education park obtained the highest ranking in the section containing the social parameters. This means that the con-

sidered design solution better meets the needs of the community and attracts more users.

Attributes	Sub-attributes	Values	Environmental and thematic park	Technological, cultural and education park	Manufacturing and industrial park
Social analysis parameters	Job opportunity	2.82	0.70	2.82	2.82
	Insertion of public spaces and green areas	3.31	3.31	3.31	1.66
	Insertion of pedestrians areas and slow mobility	3.08	3.08	3.08	1.54
	Introduction of new services	3.35	1.67	3.35	3.35
	Social activities	3.20	2.40	3.20	1.60
	Attractiveness	3.42	2.57	3.42	1.71
	Connection with the city centre	3.01	1.50	3.01	3.01
	Gentrification	2.82	1.41	2.11	2.11
25.00			16.65	24.30	17.79
Physical - Morphologic analysis parameters	Recovery of the historic and architectural pre-existences	6.63	6.63	6.63	6.63
	Compatibility of the intervention with the context	6.87	5.15	5.15	5.15
	Introduction of new volumes	4.21	4.21	3.16	2.11
	Maintainability	6.40	4.80	3.20	3.20
24.12			20.80	18.15	17.09
Environmental analysis parameters	Landscape quality	4.95	4.95	4.95	2.48
	Presence of green areas	5.25	5.25	3.94	2.62
	Safeguard of the natural native species	5.13	5.13	5.13	2.57
	Site renaturation and remediation	4.95	2.48	2.48	1.24
	Compatibility of the new natural species with the natural context	5.01	5.01	3.76	1.25
25.29			22.82	20.25	10.16
Urban analysis parameters	Iconicity	4.18	2.09	3.14	4.18
	Space flexibility	5.45	5.45	5.45	5.45
	Usability	5.45	5.45	5.45	5.45
	Flow management	4.75	3.56	3.56	3.56
	Accessibility	5.76	5.76	5.76	5.76
25.59			22.31	23.36	24.40
FINAL SCORE			82.58	86.05	69.44

Table 4.5.1-3 Average weights provided by the experts, partial and overall value of alternatives and final ranking of functional scenarios.

The second option, regarding the environmental and thematic park, is the best scenario in the categories of environmental and physical-morphologic parameters. The hypothesis of creating an urban park with multiple activities for each age group incorporates an intervention aimed at recovering the native landscape and the union of multiple functions related to the naturalistic aspect of the site. The question that this conversion option, from the physical-morphologic aspects, has obtained a high score lies in the ease of maintenance of the planned structures and public spaces, in the low insertion of new volumes and in the non-invasiveness of the intervention.
The manufacturing and industrial park does not achieve high values in the first three categories of criteria most likely linked to the strictly private function of the new intervention and the need to introduce multiple new volumes in the site. At the same time, it has the best evaluation in the section concerning urban analyses, as it converts the primitive function of the STANIC Refinery in a modern key, preserving the historical memory of a productive and industrial area. From the total values obtained by the sum of the partial attributes weights, the technological, cultural and education park solution (total score: 86,05/100) is the best alternative according to the four analysed preliminary main design categories. Considering the landscape aspect, the insertion of new social, cultural and educational functions not only allows to activate policies of urban regeneration and sustainable development of the neighbourhood, but also, through bio-phytoremediation activities for soil reclamation, it increases the feasibility and maintainability of the intervention.
The draft functional scenario ranked by the MAVT decision-making approach is illustrated in the Figure 4.5.1-6 (Figure 4.5.1-6). In addition, all the main components that particularise this adaptive reuse option for the STANIC Refinery conversion, as well as the schematic description of the current context conditions compose the building cataloguing sheet data (Table 4.5.1-4) useful to estimate the feasibility coefficient (f) and the project risk entity (r).

Figure 4.5.1-6 Design proposal of the selected architectural and functional alternative for the sustainable regeneration of the former STANIC Refinery (Author: Piludu T.).

General Data			
Building/site name	Former STANIC Refinery	Climatic zone	C
City	Bari	Orientation	South-West/North-East
Region	Puglia	Number of entrances	1
Nation	Italy	Landscape quality	*Low*
Address	Bruno Buozzi street, 84-64	Building Size	*Medium*
Site location	41°06'44.3"N 16°49'47.0"E	Site surface (m²)	530.000
Years of construction and dismission	1937/1974	Building surface (m²)	9.202
Distance from city center	4,2 Km (13 min)	Total volume (m³)	119.240
Number of existing buildings	18	Level of maintainablity	Site =*low*
Number of historic buildings	8		Context =*medium*
Building structural typology	Load-bearing structure in reinforced concrete		Infrastructures =*low*
Green areas (m²)	338.519	Reclamation interventions	*Yes*
Public space (m²)	182.279	Glazed surface	*Medium*

Existing buildings data					
Building Surfaces (m²)	Building 1	360	Volumes (m³)	Building 1	2880
	Building 2	459		Building 2	3672
	Building 3	806		Building 3	7254
	Building 4	714		Building 4	7497
	Building 5	2209		Building 5	39762
	Building 6	4654		Building 6	58175
Heights (m)	Building 1	8	Number of floors	Building 1	2
	Building 2	8		Building 2	2
	Building 3	9		Building 3	1
	Building 4	10.5		Building 4	2
	Building 5	20		Building 5	4
	Building 6	14		Building 6	1

Physical analysis Existing abandoned industrial site					
Level of decay	Site	*high*	Dampness	*high*	Presence of constraints
	Buildings	*medium*	Pests	*low*	
	Materials	*medium*	Natural attack	*medium*	Medium-high level of decay; lack of windows glasses; vandalism actions
	Structures	Pillars =*medium*	Existing plants	Electric system	
		Beams =*medium*		Exhaust system	
		Walls =*medium*		Gas plant	
		Vertical connections =*medium*		Heating system	
		Foundation =*medium*	Site conditions	Soil type	Consolidated
		Floor =*medium*		Presence of vegetation	*high*
		Roof =*high*		Level of traffic	Car =*high*
		Joints =*medium*			Bike =*low*
		Facade =*high*			Bus =*medium*
	Plants	*high*			Camion =*medium*
	Technologies	*high*			Train =*low*
	Functional decay	Parking areas =*low*			Pedestrian =*low*
		Space dimensions =*low*			Other ….
		Flows management =*low*		Level of pollution	Environmental=*high*
	Green areas	*high*			Acoustic=*medium*
	Context	*high*			Water=*medium*
Level of humidity	*medium*				Soil=*low*
Presence of asbestos	*none*				Light=*low*
Lack of building parts	*low*				Air=*medium*

Project					
Buildign transformation interventions	Cladding	*Yes*		Subtraction	*No*
	Interior design	*Yes*		Demolition	*Yes*
	Addition	Connection	*No*	Envolve	*No*
		Merge	*Yes*	Outside	*Yes*
		Elevation	*No*	Connection through public space	*Yes*
		Intrusion	*No*	Landscape and urban art	*Yes*
		Stack	*No*		
		Duplication	*No*	Excavation	*No*
N. of new buildings	5		M² added surfaces	25800	
N. of refurbished buildings	4		M³ added volumes	298827.5	
N. of demolished buildings	14		Insertion of new openings	*Yes*	
New buildings project data					
Building Surfaces (m²)	Building 1	650	Volumes (m³)	Building 1	16965
	Building 2	6875		Building 2	104500
	Building 3	8250		Building 3	70950
	Building 4	5400		Building 4	48600
	Building 5	4625		Building 5	57812.5
Heights (m)	Building 1	26.1	Number of floors	Building 1	7
	Building 2	35.65		Building 2	9
	Building 3	28.7		Building 3	6
	Building 4	9		Building 4	3
	Building 5	12.5		Building 5	4
Functional analysis			**Social analysis**		
Space flexibility and convertibility	*medium*	*high*	Stakeholders involved	Program manager, management engineer, project manager, site manager, designer, developers, architects, engineers, construction team, workers, technicians, sociologists, geologists, urbanists, landscapers, pollution manager, regulators, public administrations, heritage consultant, sponsor, investors, promoters	
Main functions	Function category	Specific function			
	Cultural	Conference center, museum, exhibition space, library, university lab, school lab, biocenter, science lab			
	Commercial	Bar, restaurant, shops, greenhouses			
	Offices	Co-working spaces, smart office,			
	Sporty	Playground			
	Education	Educational farm, workshop			
	Public spaces	Park, dog park, parking areas			
N. of services	21				
Level of accessibility and connectivity	*high*	*medium*			
Spatial flow management	*high*		Users	Community, professors, neighbors, tourists, agronomists, students and employees	
Dismantlability	*medium*				
Project building total surface (m²)	34.183				
Project green areas (m²)	411.779				
Project public spaces (m²)	99.163		Population needs	More public spaces, services, public transports, increase district attractiveness, green spaces and security and safety	
Distance from points of interest	Points of interest	Distance (Km)			
	Petruzzelli's theater	4			
	Central station	4.3			
	Politecnico	6.2			
	Hospital	4.1	Site importance for society	*medium*	
	Perotti's park	6.4	Usability and liveability	*high*	
Building connectivity	Points of interest	*medium*	Site aesthetic identity	*medium*	
	spaces and green areas	*medium*	Site attractiveness	*high*	
	City centre	*medium*	Relation society-environment-building	*medium*	
	Waterfront	*high*	Social inclusion	*high*	
	Main services	*high*	Social participation	*medium*	

Other information					
Economic feasibility	*medium*	Political feasibility	*medium*	Investments	*high and public/private*
Applied materials	Sand, gravel, wood, clay, steel, aluminium, iron, concrete, lightweight concrete, gres, granite, rock wool, low-emissive glass, photochromic glass, laminated glass, plastic materials, plaster, mortar, glue, paint	Implemented technologies	Water management, photovoltaic system, heating and cooling, electrical system, ventilation system, waste treatment plant, exhaust system, energy supply system, earthing system, geothermal system, panels, double-skin facade, glazed facade, photochromic glass, low-emissive glass, laminated glass, shutters, windows with sunscreens, thermo-acoustic insulation, ventilated facade, structural glass facade, natural ventilation and lighting, double insulation walls, radiant floor, false sealing for installations, elevators, stairs, green roof, photovoltaic roof, interior design composition	Security and safety systems	Alarm system, sensors, cameras, fire resistant wall, sprinklers, escape routes, fireproof doors, earthquake resistant foundation, seismic joints, fire resistant stairs, fireproof doors, open spaces, double height spaces
S.W.O.T. Analysis					
Strenghts				**Weaknesses**	
Flexibility of spaces; land reclamation interventions already carried out on the disused site; proximity to main sliding arteries; presence of a low building density in the dismissed refinery; presence of multiple native vegetation species; historical and characteristic production site of industrial evolution in Bari				Site extension; difficult management of the area; high ordinary and extraordinary maintenance costs; decent distance from the major points of interest of the city; high degradation of the site and of the environmental context; dormitory district totally isolated from the city context; area with high hydrogeological risk	
Opportunities				**Threats**	
Experimentation of new crops and production techniques; development of sustainable urban stitching actions; implementation of phytoremediation techniques to return the naturalistic value to this area; connection of the green areas with the Lama Lamasinata park; increase of permeable soil and green areas within the city; design of new spaces for the community to promote social inclusion; insertion of paths that favor soft mobility; insertion of functions useful to the neighborhood; improving the quality of life of the neighbourhood; insertion of new attractive polarities in the suburbs of Bari; relocation of educational and laboratory activities in the urban periphery				The vastness of the converted area does not allow optimal future management of functional and of the areas entered; lack of funds for research; high construction and landscape transformation times; possibility of copious flooding events due to the presence of the neighboring Lama Lamasinata	
Risks					
Vandalism, building defections, building vulnerability, building incompatibility with context, hazards, inadequate services for population, poor amenities, noise, increasing of construction times, construction errors, increasing of costs, technical constraints					

Table 4.5.1-4 Building cataloguing sheet (Former STANIC Refinery).

4.5.2 The former ENEL Power Plant

The Bari thermoelectric plant is situated in the peripheral Stanic district along the fast-flowing radial road of Via Bruno Buozzi. This principal urban route connects the consolidated city center with the active industrial area. The ENEL power plant borders the former petrochemical Stanic site, now totally decommissioned. The morphological settlement of this context is linear. Via Bruno Buozzi is characterised by the presence of working-class districts of the Gondar and Workers Villages, the dismissed Stanic Refinery, the thermoelectric ENEL plant and many production and storage facilities, often abandoned or underused. This suburb is composed by heterogeneous places in which there are signs of the productive history of the city, mixed with residential building typologies and few public spaces. The railway line to the north, and the Lama Lamasinata, a torrential bed that can be activated in the event of heavy rainfalls, to the west complete the perimeter of the quartier. The plant was realised by the Pugliese General Electricity Company (SGPE) in the late 1950s, with investments of Cassa del Mezzogiorno. It occupies about 6.8 hectares and is structured in three production sections. The first came into operation in 1958 while the second and third were activated in 1959. In the first period of activity, the plant was fuelled by coal. In subsequent years, liquid fuel and natural gas replaced this material. Since 2008, only natural gas has been used for the machines operation. A fire on 4 August 2013 put out of service the plant. In 2016, reclamation works began to clean up the industrial site, as well as to dismantle the metal structures of the incinerators and cooling towers. Nowadays, the existing sheds are abandoned and disused. From an architectural, morphological and compositional point of view, the former ENEL power plant is designed with rectangular, square and circular geometries neatly arranged and developed starting from two main perpendicular axes, favouring internal workers and traffic floods. Rectangular bodies host the main industrial components and functions (cooling towers, offices, engine room and energy generators). The three incinerators square-based volumes located next to the generator room, and the two chimneys are the highest structures of the lot. All the circular metal tanks are located in the rear part of the thermoelectric industrial site, completing the volumetric master plan of the existing constructions (Figures 4.5.2-1; 2; 3; 4).

Figure 4.5.2-1 Former ENEL Power Plant location.

Figure 4.5.2-2 Former ENEL Power Plant aerial view (Source: Google Earth Pro).

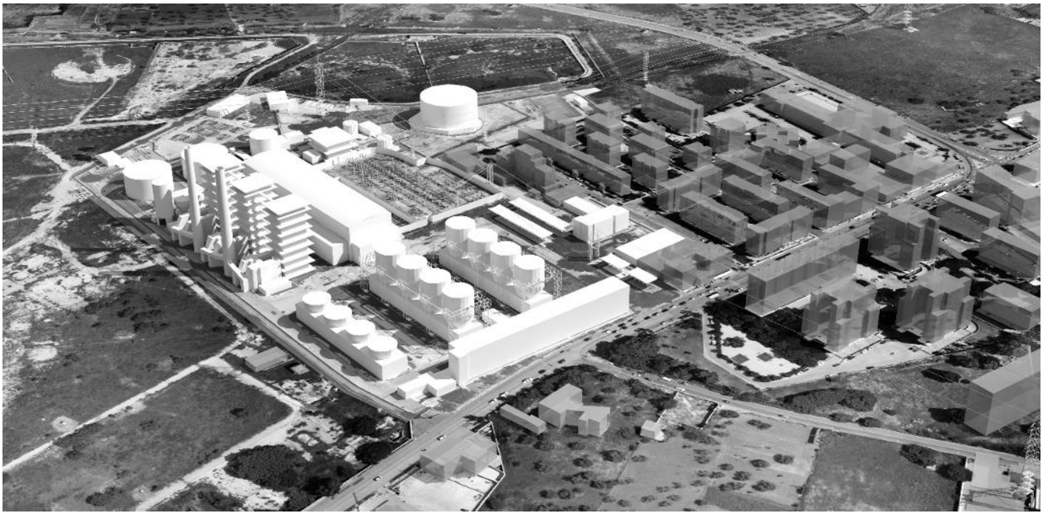


Figure 4.5.2-3 Aerial 3D view of the existing buildings and warehouses included in the former ENEL Power Plant (Software: AutoCad and Rhinoceros).

Considering the architecture of the industrial site, the office building, near the entrance to the power plant, the two chimneys, the shed containing turbines and historic power generators dating back to the 1960s represent iconic symbols of the industrial development in Bari. On the basis of these findings and according to the strategic position of the site, situated halfway between the city center and the periphery, innovative and attractive alternatives for its reuse can be hypothesised. In addition, the district committees have expressed the need to insert multifunctional incubators and co-working spaces for local citizens, as well as contemporary touristic points to increase the district attractiveness, compensating the lack of services and promoting social inclusion. Moreover, a detailed on-site analysis of the urban fabric reveals gaps in public transport and infrastructural systems. These constraints further isolate and separate this marginal context from the other parts of the city. The lack of gardens, leisure spaces and meeting places complicate neighbourhood relationships. The environmental and landscape aspects is no less important. In particular, the possibility to develop and activate sustainable environmental regeneration actions becomes tangible due to the presence of native species, natural erosive furrows and large cultivated landscapes near the case study that can increase its attractiveness.

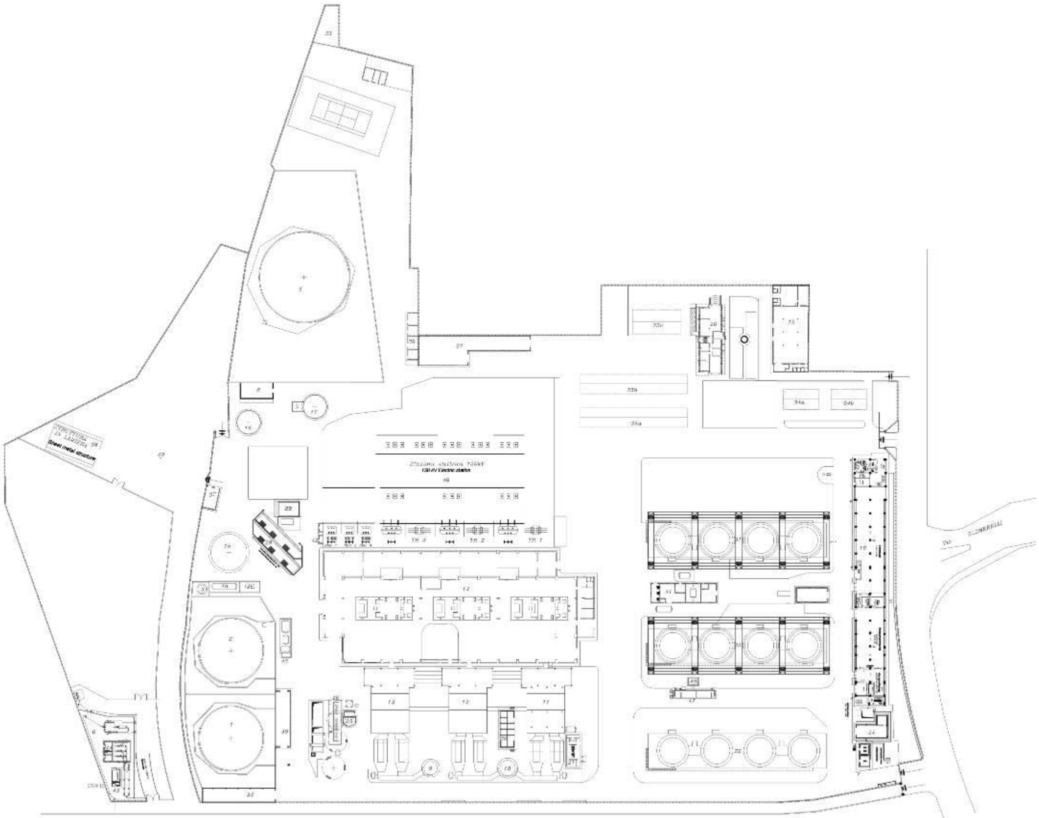


Figure 4.5.2-4 Existing former ENEL Power Plant morphology.

At the same time, many of these areas are left in total degradation. Other natural contexts are exploited as open landfills or transformed by men over the years. As emerged from these synthetic analyses of the existing, the area of the former ENEL power plant presents considerable potentials to promote reuse and refurbishment actions, as well as incorporates flexibility of spaces and compositional quality features suitable for hosting multiple functions. There is a significant environmental component, which suggests the possibility of including green areas and public spaces. The adaptive reuse activities can ensure to decrease the gap between the city center and the suburbs, perceiving social and urban reorganization and developing the concept of smart city. A complete framework of the main factors of the ENEL Power Plant provides the definition of the criteria that can be accounted for the development of feasible conversion strategies of heritage sheds. In particular, the approach applied for this case study investigates a large number of parameters, both qualitative and quantitative, identifying the best adaptive reuse scenario for the ENEL plant. For achieving this objective, the O-AHP model (Sangiorgio et al., 2017) is applied to evaluate and quantify the importance of a large set of independent sub-attributes that may occur in building conversion and adaptation processes. This type of multicriteria analysis allows to compare each criterion and sub-criterion involved in the achievement of an effective adaptive reuse intervention, quantifying attributes importance. In addition, a novel Adaptive Reuse index aimed at estimating the effectiveness of a transformation scenario can be obtained by the weighting of criteria and sub-criteria.

The O-AHP step 1 consists in the Structure of the Problem. This first part of the approach defines an effective choice regarding the best adaptive reuse strategies to implement. To this aim, four criteria i (with $i=1,\ldots,4$) are identified for explaining different aspects of the adaptive reuse models: Environmental Aspects, Social Aspects, Economic Aspects, Urban Planning Aspects (Figure 4.5.2-5).
In addition, for each scope, a set of sub-criteria j (with $j=1, \ldots, n_i$) is outlined to have an exhaustive overview of the decision problem. Subsequently, the intensity levels (normalized to 1) of every sub-criterion are characterised through a set of specified intensity ranges k (with $k=1, \ldots, m_{i,j}$).

The Environmental Aspects feature (A, $i=1$) represents the first main criterion analysed. It summarises the effects of the conversion process in terms of natural resources consumption, pollution and green areas. This attribute incorporates four environmental sub-criteria ($n_1 = 4$) linked to the adaptive reuse transformation plan:

1) Greenery (A1, $j=1$) factor underlines the insertion of green spaces in the adaptation alternative. In fact, the achievement of environmental sustainability characters and the development of urban regeneration processes can be favourited by the presence of equipped parks and gardens (Berta et al., 2016; Bottero et al., 2018; Oppio et al., 2018). Beyond this, it is widely recognized

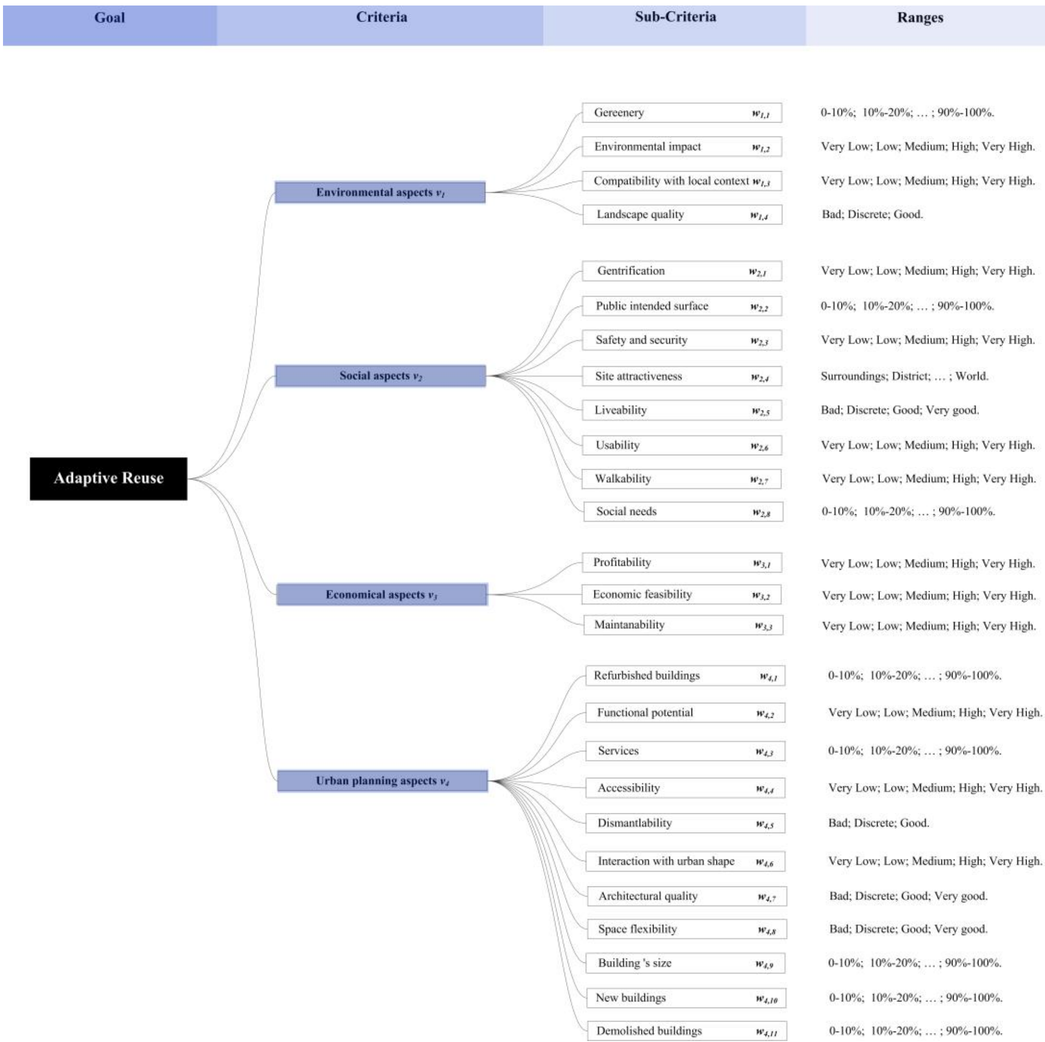


Figure 4.5.2-5 Structure of the Problem to determine the best intervention strategies for the adaptive reuse.

that the cooling effect given by the combination of evaporation and transpiration of natural essences mitigate the harmful urban heat island effect in urban districts. For this first sub-criterion ten intensity ranges are determined ($m_{1,1}=10$), varying from 0%-10% to 90%-100% of greenery;

2) Environmental impact (A2, j=2) criterion considers the positive or negative influence of industries refurbishment actions on the environment. Risks and

unfavorable aspects that can affect building adaptation and regeneration processes are analysed by this indicator. By scanning the researches of Berta et al. (Berta et al., 2018) about the measurement of urban quality through MCDM approach, a value function is structured to describe five intensity ranges ($m_{1,2}=5$): i) very low, ii) low, iii) medium, iv) high, v) very high;

3) Compatibility with local context (A3, j=3) describes the relevancy of the building adaptation scenario with the surrounding environment in order to create synergies with the existent built morphologies and typologies, strengthening the population respect of natural landscapes (Oppio et al., 2017; Oppio & Bottero, 2017). Analogously with the previous independent sub-attribute the relative value function is divided in five intensity ranges ($m_{1,3}=5$): i) very low, ii) low, iii) medium, iv) high, v) very high;
4) Landscape quality (A4, j=4) contemplates the presence of native unique natural landmarks near the decommissioned industrial site. The quality of surrounding environment, the proximity of green areas and the presence of parks are considered by this indicator. Three intensity ranges define this sub-criterion (Ferretti et al., 2014) ($m_{1,4}=3$): i) bad, ii) discrete, iii) good.

The second main criterion lists the Social Aspects (B, i=2). The micro-scopes accounted refer to the multi-faceted consequences of the building adaptation and conversion process on the local community, considering social inclusion, services and public safety features. Eight sub-criteria ($n_2=8$) compose the Social Aspects item:

1) Gentrification (B1, j=1) parameter focuses the attention on measuring the level of STANIC district improvement and renovation after conversion processes. The quartier innovativeness and progress after refurbishment and adaptation policies are evaluated through five intensity ranges ($m_{2,1}=5$) (Berta et al., 2016): i) very low, ii) low, iii) medium, iv) high, v) very high;
2) Public space surface (B2, j=2) highlights the availability of public areas to increase social relations, quantifying, for each design alternative, the total surface used to host walking and meeting open-air places (Bottero et al., 2018).

Ten intensity ranges are defined for this sub-attribute ($m_{2,2}$=10). They vary from 0%-10% to 90%-100% according to the total area assigned for public spaces in relation with the entire project surface;

3) Safety and security (B3, j=3) indicator considers site security and safeguard systems presence. Five intensity ranges are determined ($m_{2,3}$=5) according to the qualitative judgements introduced in the value function (Berta et al., 2016): i) very low, ii) low, iii) medium, iv) high, v) very high;
4) Site attractiveness (B4, j=4) outlines the leisure activities that could contribute to increase touristic local and external people flows in the re-functionalised context (Bottero et al., 2019). A qualitative scale of ranges based on functions importance describes this criterion ($m_{2,4}$=5): i) Local, ii) Municipal, iii) Regional, iv) National, v) Worldwide;
5) Liveability (B5, j=5) takes into account the future society life quality after the adoption of the reuse intervention. Four qualitative judgements are elicitated ($m_{2,5}$=4): i) Bad, ii) Discrete, iii) Good, iv) Very good;
6) Usability (B6, j=6) sub-criterion evaluates people interest in using in tranquillity all the spaces of the converted site. It explains the tangible possibility to easily reach and experience all the project functions. Five intensity ranges are determined ($m_{2,6}$=5): i) very low, ii) low, iii) medium, iv) high, v) very high;
7) Walkability (B7, j=7) includes the project capability to manage people flows (Oppio et al., 2018). The scores of this criterion can be resumed into five intensity ranges ($m_{2,7}$=5): i) very low, ii) low, iii) medium, iv) high, v) very high;
8) Social needs (B8, j=8) quantitative parameter summarises the number of local population needs satisfied by the reuse process that ensure to assess sustainability achievements (Bottero et al., 2019). It includes ten intensity ranges ($m_{2,8}$=10), varying from 0%-10% to 90%-100%.

The third criterion involves the Economic Aspects (C, i=3) that can be assumed as the interconnection points between reuse operations and economic system in terms of investments and profitability. It incorporates three sub-criteria (n_3 =3):

1) Profitability (C1, j=1) comprises the intervention profits in relation to the size of local and national business. In particular, this indicator defines the business's ability to produce a return on an investment due to the services and the market influence of each scenario. This sub-attribute is specified by five intensity ranges ($m_{3,1}$=5): i) very low, ii) low, iii) medium, iv) high, v) very high;
2) Economic feasibility (C2, j=2) analyses conversion intervention costs to determine the effectiveness of its realization. Five intensity ranges are defined ($m_{3,2}$=5): i) very low, ii) low, iii) medium, iv) high, v) very high;
3) Maintainability (C3, j=3) considers operative costs. Five intensity ranges are elicitated for this qualitative attribute ($m_{3,3}$=5): i) very low, ii) low, iii) medium, iv) high, v) very high;

The last significant main design criterion is the Urban Planning Aspects (D, i=4). It incorporates cultural heritage, urban structure, accessibility and mobility parameters, and can be exhaustively analysed considering the following sub-criteria (n_4 =11):

1) Refurbished building (D1, j=1) includes the number of regenerated historic sheds in comparison with the total buildings amount hypothesised in the intervention (Bottero et al., 2018). The related intensity ranges are expressed in percentage ($m_{4,1}$=10) varying from 0%-10% to 90%-100%;
2) Functional potential (D2, j=2) refers to the activities useful for suburbs smart development and city regeneration. This evaluation micro-scope is characterised by five intensity ranges ($m_{4,2}$=5): i) very low, ii) low, iii) medium, iv) high, v) very high;
3) Services (D3, j=3) indicator measures the number of services of the adaptive reuse project (Bottero et al., 2019). Also for this feature the intensity ranges are described in percentage ($m_{4,3}$=10), varying from 0%-10% to 90%-100%;
4) Accessibility (D4, j=4) involves both the level of pedestrian and car flows within the site (Bottero et al., 2019). The related intensity ranges ($m_{4,4}$=10) vary from: i) very low, ii) low, iii) medium, iv) high and v) very high;

5) Dismantlability (D5, j=5) considers the possibility to easily disassemble dismissed factories components, readapting them in the conversion plan. This characteristic can be distinguished, outlining three qualitative judgements ($m_{4,5}=3$): i) Bad, ii) Discrete and iii) Good;
6) Interaction with urban shape (D6, j=6) sub-attribute analyses the spatial connections between the project and the urban morphology and forms. Oppio et al. (Oppio et al., 2017) mention that physical interactions deal with the opportunity to establish synergies between the transformed volumes and the surrounding environment. Five intensity ranges are defined for this micro-scope ($m_{4,6}=5$): i) very low, ii) low, iii) medium, iv) high, v) very high;
7) Architectural quality (D7, j=7) considers the aesthetic project value. Bottero et al. (Bottero et al., 2018) define this attribute as the historic and artistic quality of the existing buildings. Four intensity ranges are specified ($m_{4,7}=4$): i) Bad, ii) Discrete, iii) Good and iv) Very good;
8) Space flexibility (D8, j=8) enunciates the capacity of the adaptive reuse intervention to preserve the readability of the building from both its original function and structure point of view (Ferretti et al., 2014). As the previous subcriterion four intensity ranges are highlighted ($m_{4,8}=4$): i) Bad, ii) Discrete, iii) Good and iv) Very good;
9) Building's size (D9, j=9) calculates the total built covered surface in relation to the area of the intervention (Bottero et al., 2019). For this quantitative parameter the intensity ranges are expressed in percentage ($m_{4,9}=10$), varying from 0%-10% to 90%-100%;
10) New buildings (D10, j=10) micro-scope summarises the number of new buildings inserted in the industrial site transformation process. Its intensity ranges are expressed in percentage ($m_{4,10}=10$), varying from 0%-10% to 90%-100%;
11) Demolished buildings (D11, j=11) indicator calculates the number of demolished buildings to accomplish site conversion. This quantitative criterion

ranges are outlined in percentage ($m_{4,11}$=10), varying from 0%-10% to 90%-100%.

The second step of the O-AHP consists in the Weights Evaluation. Considering the previously defined Structure of the Problem phase, the weights of criteria, sub-criteria and intensity ranges are described as follows:

- v_i is the weight associated with each i^{-th} criterion
- w_{ij} is the weight associated with each j^{-th} sub-criterion related to the i^{-th} criterion
- $p_{i,j,k}$ is the weight associated with each k^{-th} intensity range related to the i^{-th} criterion and j^{-th} sub-criterion.

A group of 16 professional figures specialised in the field of building refurbishment and reuse has been involved for applying the O-AHP and extrapolating the weights of the listed criteria and sub-criteria.

The selected team is composed by professors, PhD, PhD students and experts working in the field of adaptive reuse and building renovation. These actors are hereafter named as "users" or "decision makers" and, subsequently, an ID code is assigned to every participant from 1 to 16. More specifically, each user performs the O-AHP tool by assessing the 4 matrices of Saaty to get the weight w_{ij} (with i=1, …, 4), comparing the sub-criteria and 1 matrix to obtain the weights of v_i. It is worth noting that the use of the O-AHP is of basic importance. Indeed, only 2 of the 16 users do not necessitate the optimization step to reach the consistency. In addition, an example of the procedure to obtain matrices and weights is illustrated in Table 4.5.2-1 (Table 4.5.2-1) in which the judgment matrix A_1 is extrapolated by the pairwise comparisons of the four sub-criteria (n_1 =4) related to the Environmental Aspects criterion resulting to the judgments of the User 1. The obtained matrix does not satisfy the Consistency Ratio requirement CR<0.1. Hence, the O-AHP is applied to perform step 2 and gain coherent and consistent results. In the O-AHP, the decision maker adopts the semantic ranges of the O-AHP to settle the judgment ranges and the upper K^U_{ij} and lower bounds K^L_{ij} described in Table 4.5.2-2 (Table 4.5.2-2).

At this step, the problem can be formalized by the mathematical constraints using the following equations (Eq. 4.5.2-1a; 1b; 1c; 1d; 1e):

Γ(A):

$a_{ij}=1$ for $i,j=1,\dots,n$ with i=j (4.5.2-1a)

$1/9 < a_{ij} < 9$ for $i,j=1,\dots,n$ with i<j (4.5.2-1b)

$a_{ij} \leq K_{ij}^{U}$ for $(i,j) \in C^{U}$ (4.5.2-1c)

$a_{ij} > K_{ij}^{L}$ for $(i,j) \in C^{L}$ (4.5.2-1d)

$a_{ij} = 1/a_{ji}$ for $i,j=1,\dots,n$ with i>j (4.5.2-1e)

The solution to the optimization procedure is explained in Table 4.5.2-3 (Table 4.5.2-3) and exploited by the equations (Eq. 4.5.2-2a; 2b). In addition, the same scheme illustrates the optimized judgment matrix A_1^{Opt}. The resulting optimised matrix satisfy the Consistency Ratio requirement CR<0.1 and derived consistent weights w_{1j}.

min CI(A) (4.5.2-2a)

subject to Γ(A) (4.5.2-2b)

Environmental aspects	***A1***	***A2***	***A3***	***A4***	***CR***
Greenery (A1)	1.0	4.0	0.3	0.2	0.15
Environmental impact (A2)	0.3	1.0	0.5	0.1	
Compatibility with local context (A3)	3.0	2.0	1.0	0.7	
Landscape quality (A4)	6.0	9.0	1.5	1.0	

Table 4.5.2-1 User1: Judgment Matrix A_1, and CR obtained for the intensity ranges related to “Environmental aspects” criterion.

K^U_{IJ}	K^L_{IJ}
4	2
1/1.5	1/3
1/5	1/6
1/2	1/4
1/8	1/9
1/2.5	1/1.5

Table 4.5.2-2 Upper and lower bound for the optimization procedure of the Judgment Matrix A_1.

A_1^{Opt}	*A1*	*A2*	*A3*	*A4*	*CR*	w_{1j}
Greenery (A1)	1.0	2.0	0.5	0.2	0.01	0.12
Environmental impact (A2)	0.5	1.0	0.3	0.1		0.07
Compatibility with local context (A3)	2.1	3.0	1.0	0.5		0.24
Landscape quality (A4)	5.6	8.2	2.0	1.0		0.57

Table 4.5.2-3 User1: Judgment Matrix A_1^{Opt}, weights, and CR obtained for the intensity ranges related to “Environmental aspects” criterion.

The Weighting Evaluation step is carried out for all the attributes and sub-attributes, as well as across all different experts to quantify the local weights. This procedure is repeated with the aim to weight each criterion and option of the decision problem and for every involved user. The values $p_{i,j,k}$ are not judged by the users but are extracted by the related literature and normalized to 1.

In the third and final step of the Summary of Priority, the global weights associated with each sub-criterion are calculated, for each users responses, by multiplying the criteria weight with the sub-criteria weight, as in the classical AHP (Eq. 4.5.2-3):

$$w'_{i,j} = v_i * w_{i,j} \tag{4.5.2-3}$$

Once all the decision makers perform the O-AHP process, it is possible to measure the influence of every design factor for the success of the adaptive reuse project on the basis of the expert’s judgments. The obtained tabulated values are showed in Table 4.5.2-4 (Table 4.5.2-4). Figure 4.5.2-6 (Figure 4.5.2-6) illustrates the statistical graph (Boxplot) about the influence of each sub-criterion in the project feasibility through adaptive reuse models. More specifically, the boxes represent the distribution of weights values. In addition, the black horizontal line inside the boxes denotes the median of the sample. The vertical dotted line englobes all the results which are not considered outliers, while the box includes all the outputs values within the 25th and 75th percentile of the population. This result shows that there is a very low variation of opinions among the selected users, demonstrating a good robustness of the analysis.

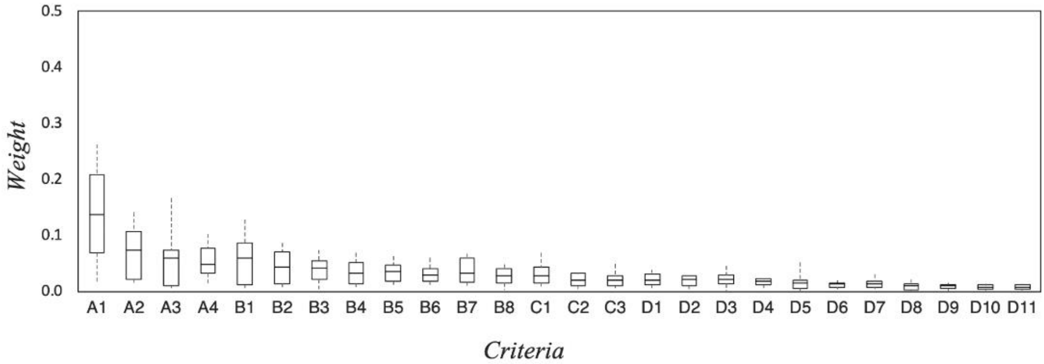


Figure 4.5.2-6 Boxplot of the importance (global weight) of each sub-criterion in the effectiveness of a transformation project through adaptive reuse.

Indeed, the influence of every macro and micro-scope in the effectiveness of the adaptive reuse design scenario can be quantified through the average scores of the global weights (Table 4.5.2-4). Figure 4.5.2-7 (Figure 4.5.2-7) illustrates the importance of the parameters expressed in percentage.

The graph displays that the sub-criteria most involved in urban regeneration processes are related to economy and environmental sustainability aspects, considering the feasibility of adaptive reuse processes and profits that can be inherited from the new functions and attractions planned in the lot. Not less important are the social aspects, since they provide to identify the current needs of population and the shortcomings of the urbanized peripheral territory.

ID	Criteria	ID	Sub-Criteria	$w_{i,j}$	Global weights	Intensity ranges	$p_{i,j,k}$	Weight
A	Environmental aspects	A1	Greenery	$w_{1,1}$	0.082	90-100%	$p_{1,1,1}$	1.0
						80-90%	$p_{1,1,2}$	0.9
						70-80%	$p_{1,1,3}$	0.8
						60-70%	$p_{1,1,4}$	0.7
						50-60%	$p_{1,1,5}$	0.6
						40-50%	$p_{1,1,6}$	0.5
						30-40%	$p_{1,1,7}$	0.4
						20-30%	$p_{1,1,8}$	0.3
						10-20%	$p_{1,1,9}$	0.2
						0-10%	$p_{1,1,10}$	0.1
		A2	Environmental impact	$w_{1,2}$	0.059	Very Low	$p_{1,2,1}$	1
						Low	$p_{1,2,2}$	0.8
						Medium	$p_{1,2,3}$	0.6
						High	$p_{1,2,4}$	0.4
						Very High	$p_{1,2,5}$	0.2
		A3	Compatibility with local context	$w_{1,3}$	0.060	Very High	$p_{1,3,1}$	1
						High	$p_{1,3,2}$	0.8
						Medium	$p_{1,3,3}$	0.6
						Low	$p_{1,3,4}$	0.4
						Very Low	$p_{1,3,5}$	0.2
		A4	Landscape quality	$w_{1,4}$	0.157	Good	$p_{1,4,1}$	1
						Discrete	$p_{1,4,2}$	0.66
						Bad	$p_{1,4,3}$	0.33
B	Social aspects	B1	Gentrification	$w_{2,1}$	0.017	Very High	$p_{2,1,1}$	1
						High	$p_{2,1,2}$	0.8
						Medium	$p_{2,1,3}$	0.6
						Low	$p_{2,1,4}$	0.4
						Very Low	$p_{2,1,5}$	0.2
		B2	Public space surface	$w_{2,2}$	0.024	90-100%	$p_{2,2,1}$	1.0
						80-90%	$p_{2,2,2}$	0.9
						70-80%	$p_{2,2,3}$	0.8
						60-70%	$p_{2,2,4}$	0.7
						50-60%	$p_{2,2,5}$	0.6
						40-50%	$p_{2,2,6}$	0.5
						30-40%	$p_{2,2,7}$	0.4
						20-30%	$p_{2,2,8}$	0.3
						10-20%	$p_{2,2,9}$	0.2
						0-10%	$p_{2,2,10}$	0.1
		B3	Safety and security	$w_{2,3}$	0.039	Very High	$p_{2,3,1}$	1
						High	$p_{2,3,2}$	0.8
						Medium	$p_{2,3,3}$	0.6
						Low	$p_{2,3,4}$	0.4
						Very Low	$p_{2,3,5}$	0.2
		B4	Site attractiveness	$w_{2,4}$	0.015	Worldwide	$p_{2,4,1}$	1
						National	$p_{2,4,2}$	0.8
						Regional	$p_{2,4,3}$	0.6
						Municipal	$p_{2,4,4}$	0.4
						Local	$p_{2,4,5}$	0.2
		B5	Liveability	$w_{2,5}$	0.044	Very Good	$p_{2,5,1}$	1
						Good	$p_{2,5,2}$	0.75
						Discrete	$p_{2,5,3}$	0.5
						Bad	$p_{2,5,4}$	0.25
		B6	Usability	$w_{2,6}$	0.029	Very High	$p_{2,6,1}$	1
						High	$p_{2,6,2}$	0.8
						Medium	$p_{2,6,3}$	0.6
						Low	$p_{2,6,4}$	0.4
						Very Low	$p_{2,6,5}$	0.2
		B7	Walkability	$w_{2,7}$	0.026	Very High	$p_{2,7,1}$	1
						High	$p_{2,7,2}$	0.8
						Medium	$p_{2,7,3}$	0.6
						Low	$p_{2,7,4}$	0.4
						Very Low	$p_{2,7,5}$	0.2
		B8	Social needs	$w_{2,8}$	0.050	90-100%	$p_{2,8,1}$	1.0
						80-90%	$p_{2,8,2}$	0.9
						70-80%	$p_{2,8,3}$	0.8
						60-70%	$p_{2,8,4}$	0.7
						50-60%	$p_{2,8,5}$	0.6
						40-50%	$p_{2,8,6}$	0.5
						30-40%	$p_{2,8,7}$	0.4
						20-30%	$p_{2,8,8}$	0.3
						10-20%	$p_{2,8,9}$	0.2
						0-10%	$p_{2,8,10}$	0.1
C	Economic aspects	C1	Profitability	$w_{3,1}$	0.066	Very High	$p_{3,1,1}$	1
						High	$p_{3,1,2}$	0.8
						Medium	$p_{3,1,3}$	0.6
						Low	$p_{3,1,4}$	0.4
						Very Low	$p_{3,1,5}$	0.2
		C2	Economic feasibility	$w_{3,2}$	0.060	Very High	$p_{3,2,1}$	1
						High	$p_{3,2,2}$	0.8
						Medium	$p_{3,2,3}$	0.6
						Low	$p_{3,2,4}$	0.4
						Very Low	$p_{3,2,5}$	0.2
		C3	Maintanability	$w_{3,3}$	0.048	Very Low	$p_{3,3,1}$	1
						Low	$p_{3,3,2}$	0.8
						Medium	$p_{3,3,3}$	0.6
						High	$p_{3,3,4}$	0.4
						Very High	$p_{3,3,5}$	0.2
D	Urban planning aspects	D1	Refurbished building	$w_{4,1}$	0.027	90-100%	$p_{4,1,1}$	1.0
						80-90%	$p_{4,1,2}$	0.9
						70-80%	$p_{4,1,3}$	0.8
						60-70%	$p_{4,1,4}$	0.7
						50-60%	$p_{4,1,5}$	0.6
						40-50%	$p_{4,1,6}$	0.5
						30-40%	$p_{4,1,7}$	0.4
						20-30%	$p_{4,1,8}$	0.3
						10-20%	$p_{4,1,9}$	0.2
						0-10%	$p_{4,1,10}$	0.1
		D2	Functional potential	$w_{4,2}$	0.025	Very High	$p_{4,2,1}$	1
						High	$p_{4,2,2}$	0.8
						Medium	$p_{4,2,3}$	0.6
						Low	$p_{4,2,4}$	0.4
						Very Low	$p_{4,2,5}$	0.2
		D3	Services	$w_{4,3}$	0.017	90-100%	$p_{4,3,1}$	1.0
						80-90%	$p_{4,3,2}$	0.9
						70-80%	$p_{4,3,3}$	0.8
						60-70%	$p_{4,3,4}$	0.7
						50-60%	$p_{4,3,5}$	0.6
						40-50%	$p_{4,3,6}$	0.5
						30-40%	$p_{4,3,7}$	0.4
						20-30%	$p_{4,3,8}$	0.3
						10-20%	$p_{4,3,9}$	0.2
						0-10%	$p_{4,3,10}$	0.1
		D4	Accessibility	$w_{4,4}$	0.031	Very High	$p_{4,4,1}$	1
						High	$p_{4,4,2}$	0.8
						Medium	$p_{4,4,3}$	0.6
						Low	$p_{4,4,4}$	0.4
						Very Low	$p_{4,4,5}$	0.2
		D5	Dismantlability	$w_{4,5}$	0.015	Good	$p_{4,5,1}$	1
						Discrete	$p_{4,5,2}$	0.66
						Bad	$p_{4,5,3}$	0.33
		D6	Interaction with urban shape	$w_{4,6}$	0.021	Very High	$p_{4,6,1}$	1
						High	$p_{4,6,2}$	0.8
						Medium	$p_{4,6,3}$	0.6
						Low	$p_{4,6,4}$	0.4
						Very Low	$p_{4,6,5}$	0.2
		D7	Architectural quality	$w_{4,7}$	0.030	Very Good	$p_{4,7,1}$	1
						Good	$p_{4,7,2}$	0.75
						Discrete	$p_{4,7,3}$	0.5
						Bad	$p_{4,7,4}$	0.25
		D8	Space flexibility	$w_{4,8}$	0.034	Very Good	$p_{4,8,1}$	1
						Good	$p_{4,8,2}$	0.75
						Discrete	$p_{4,8,3}$	0.5
						Bad	$p_{4,8,4}$	0.25
		D9	Building's size	$w_{4,9}$	0.011	0-10%	$p_{4,9,1}$	1.0
						10-20%	$p_{4,9,2}$	0.9
						20-30%	$p_{4,9,3}$	0.8
						30-40%	$p_{4,9,4}$	0.7
						40-50%	$p_{4,9,5}$	0.6
						50-60%	$p_{4,9,6}$	0.5
						60-70%	$p_{4,9,7}$	0.4
						70-80%	$p_{4,9,8}$	0.3
						80-90%	$p_{4,9,9}$	0.2
						90-100%	$p_{4,9,10}$	0.1
		D10	New buildings	$w_{4,10}$	0.007	0-10%	$p_{4,10,1}$	1.0
						10-20%	$p_{4,10,2}$	0.9
						20-30%	$p_{4,10,3}$	0.8
						30-40%	$p_{4,10,4}$	0.7
						40-50%	$p_{4,10,5}$	0.6
						50-60%	$p_{4,10,6}$	0.5
						60-70%	$p_{4,10,7}$	0.4
						70-80%	$p_{4,10,8}$	0.3
						80-90%	$p_{4,10,9}$	0.2
						90-100%	$p_{4,10,10}$	0.1
		D11	Demolished buildings	$w_{4,11}$	0.007	0-10%	$p_{4,11,1}$	1.0
						10-20%	$p_{4,11,2}$	0.9
						20-30%	$p_{4,11,3}$	0.8
						30-40%	$p_{4,11,4}$	0.7
						40-50%	$p_{4,11,5}$	0.6
						50-60%	$p_{4,11,6}$	0.5
						60-70%	$p_{4,11,7}$	0.4
						70-80%	$p_{4,11,8}$	0.3
						80-90%	$p_{4,11,9}$	0.2
						90-100%	$p_{4,11,10}$	0.1

Table 4.5.2-4 O-AHP final weights for each criterion.

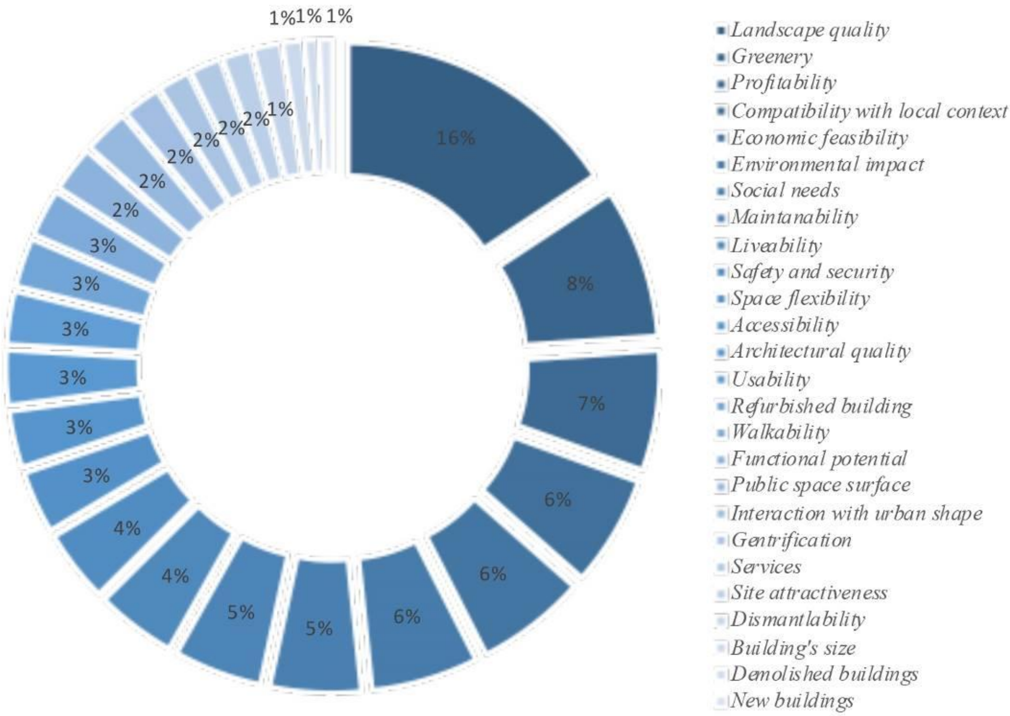


Figure 4.5.2-7 Pie chart of the importance of each sub-criterion (expressed in percentage) in the effectiveness of a transformation project through adaptive reuse.

Once the weights of each category and subcategory have been evaluated using the O-AHP methodology, different compositional and functional design alternatives are elaborated. The analysis of the context and the morphological, landscape and architectural peculiarities of the ENEL power plant ensures to hypothesise diverse social, functional and technological scenarios applying adaptive reuse approaches.
The extracted results pay the attention at the historical and architectural uniqueness of the site and the primary social needs to satisfy. In particular, the students of the Architecture and Architectural Composition II course of the Polytechnic of Bari produce six distinct adaptive reuse design scenarios that are studied on the basis of the compositional, spatial, functional and technological fields that each alternative incorporates.

The hypothesised master plans and functions are respectively showed in Figure 4.5.2-8 (Figure 4.5.2-8) and described as follows:

a) Ideal Lux project: the first design option incorporates multifunctional spaces and services for the residence. In addition, the same are juxtaposed into a wider functional program based on the Apulian film and theatre production due to the strong demand and attractiveness of this artistic sector in the region. The project concept refers to the creation of a single big incubator of culture and businesses based on scenic arts for implementing policies aimed at tourism and increasing people knowledge on Apulian film culture and history. The pre-existing warehouses and offices are re-functionalized and linked to each other by squares and suspended pathways. A steel cover surmounts the central historic shed without affecting the original structure;
b) pENELope project: the plan tries, on the one hand, to provide an innovative function to the dismissed power plant, and, on the other hand, to redevelop and recover the adjacent houses. The adaptive reuse intervention involves the conversion of the decommissioned production context into a fashion academy. Three different autonomous spatial units, physically connected to each other, compose the functional program of the master plan. The office building, located near the main entrance, is technologically re-functionalized, adopting sustainable options on the façades and roof. This infrastructure contains the services for welcoming visitors. Catwalks and suspended walkways link together the two cooling towers to host showrooms and event spaces. The transformer warehouse is hypothesised as the production heart of the academy, converting its surfaces into classrooms, hubs and co-working areas;
c) Sharespace project: the third alternative proposed regenerates the dismissed industrial context, preserving the historical pre-existing structures. The design idea conceives the spaces as large containers for spin-offs, start-ups and smart offices. To achieve population interest, the site also incorporates a co-working hub. The master plan connects the ENEL thermoelectric plant with the inhabited center by eliminating spatial barriers. In addition, this proposal

tries to establish a connection of the roads between the residential buildings and the designed area, allowing to modify the neighbourhood into a smart space with slow mobility streets. Squares, large green spaces, and meeting places substitute the existing empty surfaces;

d) ExSC project: the Extreme Sport Center is conceptualized to give greater centrality to the Stanic district, reusing the unused heritage site into a polyfunctional sports center. The master plan englobes diverse areas used for bungee jumping, skateboard park and climbing activities. One volume is dedicated to water sports. The other sports activities are placed near the main entrance. A spacious square occupies the center of the project, providing a space for establishing social relations between citizens. To enrich the number of services, a shopping mall, strictly linked with the residences, completes the project;

e) PASS project: the Stanic Student Art Park is designed with the intention of inserting exhibition and education functions directly connected with the main services of the Fiera del Levante site. The volume at the entrance hosts the management and administrative functions of the University. The existing central turbine block is adapted into a design and co-working laboratories and exhibition hall. The adjacent classrooms are linked to the existing building through raised paths. Students residences are located in the rear part of the master plan. The central square represents the filter space to control flows. Services for the residence, gardens and parking spaces supplement the plan;

f) NAAD project: the transformation idea deepens and analyses the existing social needs, hypothesising a multifunctional space to host the Academy of Fine Arts of Bari, currently without adequate and flexible infrastructure to promote laboratory and didactic activities. Considering the urbanistic aspect, the proposal reuses the existing routes and the dismissed railway line. The introduction of oblique paths allows to set up visual cones in order to frame the different functions of the lot. The functional program of this design alternative includes drawing, painting and sculpture workshops, conference rooms, classrooms and services for the community.

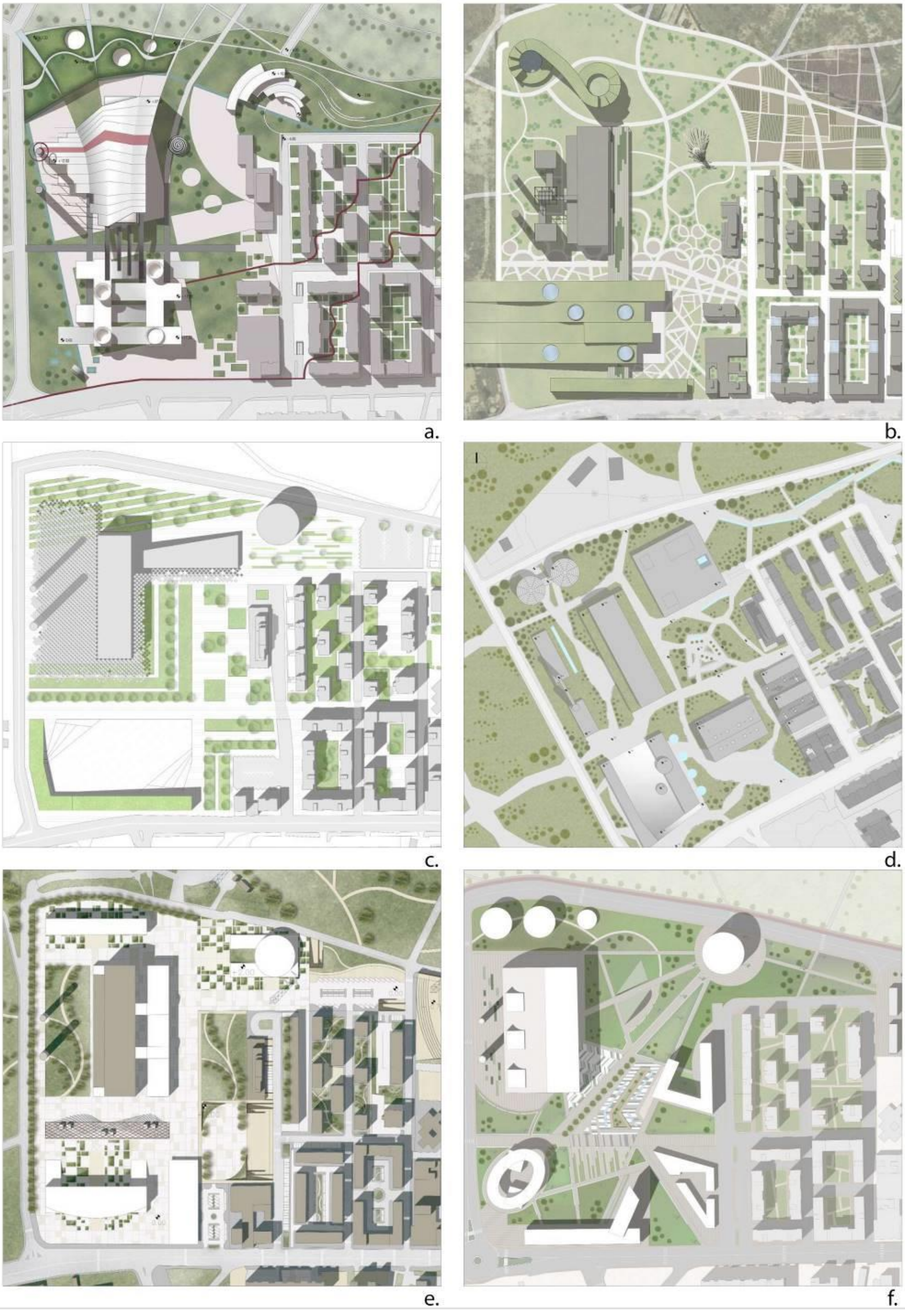


Figure 4.5.2-8 Design proposals for the refurbishment of the former Enel Power Station of Bari. Students of Design and architectural composition II + Lab. Course of Politecnico di Bari (DICAR).

Once each of the six selected design proposals has been described, the next step consists in the definition of the qualitative and quantitative data and relative values of $p_{i,j,k}$ illustrated in the performace matrix (Table 4.5.2-5).

The Performace matrix ensures to provide a general overview of parameters standardised scores according to each possible intervention scenario. Subsequently, these data are used in the index evaluation together with the weights $w'_{i,j}$ obtained in Table 4.5.2-4 to choose the design alternative with the greatest adaptive reuse potential.

		a		b		c		d		e		f	
CATEGORIES	ATTRIBUTES	Values	Pi,j,k	Values	Pi,j,k	Values	Pi,j,k	Values	Pi,j,k	Values	Pi,j,k	Values	Pi,j,k
Environmental aspects	Greenery	46.397	0.6	46.011	0.6	25.510	0.4	37.717	0.5	17.606	0.3	33.413	0.5
	Environmental impact	High	0.4	Very High	0.2	Very Low	1	Medium	0.6	Low	0.8	Medium	0.6
	Compatibility with local context	Medium	0.6	Medium	0.6	High	0.8	Medium	0.6	Very High	1	Very low	0.2
	Landscape quality	Good	1	Good	1	Bad	0.33	Discrete	0.66	Bad	0.33	Discrete	0.66
Social aspects	Gentrification	Very High	1	High	0.8	Medium	0.6	High	0.8	Very High	1	Very High	1
	Public space surface	31.853	0.5	32.239	0.5	52.740	0.7	40.533	0.6	60.644	0.8	44.837	0.6
	Safety and security	High	0.8	Medium	0.6	Very High	1	High	0.8	Very High	1	Very High	1
	Site attractiveness	Regional	0.6	Worldwide	1	National	0.8	Local	0.2	Regional	0.6	Regional	0.6
	Liveability	Good	0.75	Good	0.75	Discrete	0.5	Good	0.75	Very Good	1	Very Good	1
	Usability	High	0.8	Medium	0.6	Very High	1	High	0.8	Very High	1	Very High	1
	Walkability	High	0.8	Medium	0.6	Very High	1	High	0.8	Very High	1	High	0.8
	Social needs	12	0.8	11	0.8	10	0.7	13	0.9	13	0.9	11	0.8
Economic aspects	Profitability	Very High	1	High	0.8	Very High	1	High	0.8	High	0.8	High	0.8
	Economic feasibility	Low	0.4	Very Low	0.2	Very High	1	Low	0.4	High	0.8	Medium	0.6
	Maintanability	Medium	0.6	Medium	0.6	Very High	1	Medium	0.6	Very High	1	High	0.8
Urban planning aspects	Refurbished building	6	0.8	7	0.9	4	0.5	5	0.7	3	0.4	8	1
	Functional potential	High	0.8	High	0.8	Very High	1	Medium	0.6	Very High	1	Very High	1
	Services	18	1	15	0.9	10	0.6	9	0.5	16	0.9	14	0.8
	Accessibility	High	0.8	Medium	0.6	Medium	0.6	High	0.8	Very High	1	High	0.8
	Dismantlability	Discrete	0.66	Good	1	Bad	0.33	Discrete	0.66	Bad	0.33	Good	1
	Interaction with urban shape	Medium	0.6	Low	0.4	High	0.8	High	0.8	Very High	1	Low	0.4
	Architectural quality	Very Good	1	Very Good	1	Discrete	0.5	Discrete	0.5	Good	0.75	Good	0.75
	Space flexibility	Discrete	0.5	Very Good	1	Good	0.75	Discrete	0.5	Good	0.75	Good	0.75
	Building's size	30.993	0.3	44.098	0.1	23.246	0.5	35.485	0.2	25.914	0.5	33.735	0.3
	New buildings	3	0.6	3	0.6	2	0.7	5	0.2	5	0.2	6	0.1
	Demolished buildings	9	0.3	8	0.4	11	0.1	10	0.2	12	0.1	7	0.5

Table 4.5.2-5 Performace matrix with pairwise comparison between scenarios and sub-criteria.

The selection of the best design solution to transform the abandoned site of the former ENEL Power Station in Bari by using I_{AR} composes the third and final phase of the proposed methodology. The final matrix of the values ($w'_{i,j} * p_{i,j,k}$) of each individual parameter and for each of the six identified reuse options are schematized in Table 4.5.2-6 (Table 4.5.2-6) (the index I_{AR} is obtained by summing these values according to equation 4.5.2-3). It is possible to derive the final I_{AR} values of each parameter depending on the design solution indicated by summing the values of Table 4.5.2-6 (Table 4.5.2-6) according to the equation (Eq. 4.5.2-4):

$$I_{AR} = w'_{1,1} * p_{1,1,k} + w'_{1,2} * p_{1,2,k} + w'_{1,3} * p_{1,3,k} + \cdots + w'_{4,11} * p_{4,11,k} \qquad (4.5.2\text{-}4)$$

Code	$w'_{i,j}$	a (w'i,j * pi,j,k)	b (w'i,j * pi,j,k)	c (w'i,j * pi,j,k)	d (w'i,j * pi,j,k)	e (w'i,j * pi,j,k)	f (w'i,j * pi,j,k)
A1	8.21	4.93	4.93	3.28	4.11	2.46	4.11
A2	5.86	2.35	1.17	5.86	3.52	4.69	3.52
A3	6.04	3.62	3.62	4.83	3.62	6.04	1.21
A4	15.74	15.74	15.74	5.19	10.39	5.19	10.39
B1	1.72	1.72	1.37	1.03	1.37	1.72	1.72
B2	2.44	1.22	1.22	1.71	1.46	1.95	1.46
B3	3.93	3.14	2.36	3.93	3.14	3.93	3.93
B4	1.55	0.93	1.55	1.24	0.31	0.93	0.93
B5	4.37	3.28	3.28	2.19	3.28	4.37	4.37
B6	2.89	2.32	1.74	2.89	2.32	2.89	2.89
B7	2.59	2.07	1.56	2.59	2.07	2.59	2.07
B8	4.98	3.99	3.99	3.49	4.48	4.48	3.99
C1	6.56	6.56	5.25	6.56	5.25	5.25	5.25
C2	6.01	2.40	1.20	6.01	2.40	4.81	3.61
C3	4.82	2.89	2.89	4.82	2.89	4.82	3.86
D1	2.66	2.13	2.40	1.33	1.87	1.07	2.66
D2	2.49	1.99	1.99	2.49	1.49	2.49	2.49
D3	1.69	1.69	1.52	1.01	0.84	1.52	1.35
D4	3.09	2.48	1.86	1.86	2.48	3.09	2.48
D5	1.50	0.99	1.50	0.49	0.99	0.49	1.50
D6	2.06	1.24	0.82	1.65	1.65	2.06	0.82
D7	3.00	3.00	3.00	1.50	1.50	2.25	2.25
D8	3.39	1.70	3.39	2.54	1.70	2.54	2.54
D9	1.08	0.32	0.11	0.54	0.22	0.54	0.32
D10	0.71	0.43	0.43	0.50	0.14	0.14	0.07
D11	0.73	0.22	0.29	0.07	0.15	0.07	0.36
		a	b	c	d	e	f
I_{AR} (Sum)		**73.32**	69.16	69.61	**63.63**	72.40	70.14
Ranking		1°	5°	4°	6°	2°	3°

Table 4.5.2-6 Final matrix of weigts and ranking of scenarios.

Considering the percentages summarised in the final matrix (Table 4.5.2-6), the Ideal Lux project (73.32%) best suits the needs of the population, creates new working realities on the territory and respects the surrounding landscape. In addition, it is possible to observe that all the six design scenarios final scores present minimal deviations. This statement means that all the analysed alternatives are valid. In fact, the ExSC project that scored the lowest (63.63%) differs slightly from the best-case adaptive reuse solution.

The presence of new modern and technological incubators, the size of the disused industrial site, the demolition of some dilapidated pre-existences and the large surfaces of the warehouses to be re-functionalized have lowered the actual potential of the site conversion scenarios. In terms of sustainability and preservation of the existent, introducing modern volumes or recovering sheds that are in an advanced state of degradation decreases the feasibility of the intervention, since it will require higher costs for its construction. At the same time, good design of urban spaces, greenery and infrastructure improves the liveability, accessibility and safety of places, transforming the suburbs into sustainable, technological and functional smart districts to meet the needs of population.

The following building cataloguing sheet (Table 4.5.2-7) englobes the main features of the existing ENEL Power Plant and all the information about the adaptive reuse hypothesis arisen by the application of O-AHP decision support tool. In the next chapter the different design solutions are evaluated through the DCS, estimating for each of them the feasibility coefficient (f) and the risk entity score (r).

General Data			
Building/site name	Former ENEL Power Plant	Climatic zone	C
City	Bari	Orientation	North - South
Region	Puglia	Number of entrances	2
Nation	Italy	Landscape quality	*Low*
Address	Bruno Buozzi Street, 35, 70132 Bari	Building Size	*Medium*
Site location	41°06'59.2"N 16°50'13.0"E	Site surface (m^2)	78.250
Years of construction and dismission	1958 / 2013	Building surface (m^2)	17.086
Distance from city center	3.4 km (9 min)	Total volume (m^3)	210.213
Number of existing buildings	56	Level of maintainablity	Site =*medium*
Number of historic buildings	4		Context =*medium*
Building structural typology	Bearing structure in reinforced concrete or steel, metal reticular beams, chimneys and tanks		Infrastructures =*medium*
Green areas (m^2)	7.825	Reclamation interventions	*Yes*
Public space (m^2)	53.339	Glazed surface	*Low*

Existing buildings data					
Building Surfaces (m^2)	Building 1	1301	Volumes (m^3)	Building 1	15942
	Building 2	1072		Building 2	14775
	Building 3	1072		Building 3	14775
	Building 4	1072		Building 4	14775
	Building 5	208		Building 5	1649
	Building 6	567		Building 6	2295
	Building 7	34		Building 7	2040
	Building 8	23		Building 8	1380
	Building 9	5065		Building 9	90902
	Building 10	1154		Building 10	15000
	Building 11	1111		Building 11	20000
	Building 12	310		Building 12	3479
	Building 13	196		Building 13	2134
	Building 14	183		Building 14	2000
	Building 15	246		Building 15	984
Heights (m)	Building 1	12.25	Number of floors	Building 1	3
	Building 2	13.78		Building 2	1
	Building 3	13.78		Building 3	1
	Building 4	13.78		Building 4	1
	Building 5	7.93		Building 5	2
	Building 6	4.05		Building 6	1
	Building 7	60.00		Building 7	1
	Building 8	60.00		Building 8	1
	Building 9	17.95		Building 9	4
	Building 10	13.00		Building 10	1
	Building 11	18.00		Building 11	1
	Building 12	11.22		Building 12	5
	Building 13	10.89		Building 13	1
	Building 14	10.93		Building 14	1
	Building 15	4.00		Building 15	1

Physical analysis					
Existing abandoned industrial site					
Level of decay	Site	*low*	Dampness	*medium*	Presence of constraints
	Buildings	*low*	Pests	*low*	
	Materials	*medium*	Natural attack	*low*	High building density in the lot; size of buildings disproportionate to the context; presence of high voltage Terna plant
	Structures	Pillars = *low*	Existing plants	Gas and electric systems	
		Beams = *medium*		Water and exhaust systems	
		Walls = *low*		Heating system	
		Vertical connections = *low*		Fire-fighting system	
		Foundation = *medium*	Site conditions	Soil type	Consolidated
		Floor = *low*		Presence of vegetation	*low*
		Roof = *medium*		Level of traffic	Car = *high*
		Joints = *medium*			Bike = *low*
		Facade = *medium*			Bus = *medium*
	Plants	*medium*			Camion = *medium*
	Technologies	*medium*			Train = *low*
	Functional decay	Parking areas = *low*			Pedestrian = *low*
		Space dimensions = *low*			Other ….
		Flows management = *low*		Level of pollution	Environmental=*high*
	Green areas	*medium*			Acoustic=*medium*
	Context	*medium*			Water=*low*
Level of humidity	*medium*				Soil=*medium*
Presence of asbestos	*none*				Light=*low*
Lack of building parts	*none*				Air=*medium*
Project					
Buildign transformation interventions	Cladding	*Yes*		Subtraction	*No*
	Interior design	*Yes*		Demolition	*Yes*
	Addition	Connection	*Yes*	Envolve	*Yes*
		Merge	*No*	Outside	*Yes*
		Elevation	*No*	Connection through public space	*Yes*
		Intrusion	*Yes*	Landscape and urban art	*Yes*
		Stack	*Yes*		
		Duplication	*No*	Excavation	*No*
N. of new buildings	3		M^2 added surfaces	5130	
N. of refurbished buildings	6		M^3 added volumes	47.348	
N. of demolished buildings	50		Insertion of new openings	*Yes*	
New buildings project data					
Building Surfaces (m^2)	Building 1	3458	Volumes (m^3)	Building 1	41.496
	Building 2	836		Building 2	2926
	Building 3	836		Building 3	2926
Heights (m)	Building 1	20	Number of floors	Building 1	7
	Building 2	3.5		Building 2	1
	Building 3	3.5		Building 3	1
	Functional analysis			**Social analysis**	
Space flexibility and convertibility	*high*	*medium*	Stakeholders involved	Program manager, management engineer, project manager, facility manager, consultants, architects, designer, graphic designer, construction team, workers, sociologists, engineers, technicians, surveyors, urbanists, landscapers, pollution manager, policy makers, public administrations, cultural associations, heritage consultant, merketeers, promoters, sponsors, investors	
Main functions	Function category	Specific function			
	Cultural	Theater, concert hall, exhibition spaces, cinema			
	Commercial	Bar, restaurant, pub			
	Offices	Smart office			
	Sporty	Dancing school			
	Education	Acting school, music school, singing school, academy of fine arts			
	Spaces for fun	Open air event space			
	Public spaces	Park, square, arena, parking areas			
N. of services	18				
Level of accessibility and connectivity	*high*	*high*			
Spatial flow management	*medium*		Users	Community, actors, associations, neighbors, tourists, workers, students	
Dismantlability	*medium*				
Project building total surface (m^2)	12.397				
Project green areas (m^2)	46.397				
Project public spaces (m^2)	19.456		Population needs	Increase of public spaces, increase of services, increase of green spaces, modern urban infrastructures, increase district safety and security	
Distance from points of interest	Points of interest	Distance (Km)			
	Airport	8			
	Petruzzelli theater	3.7			
	Team theater	11			
	Polytechnic of Bari	4.7			
	Fiera del Levante	4			
	Aldo Moro University	2.9	Site importance for society	*high*	
	Pane e pomodoro beach	5.9	Usability and liveability	*medium*	

Building connectivity	Points of interest	*high*	Site aesthetic identity	*high*	
	Parking areas, public spaces and green areas	*medium*	Site attractiveness	*medium*	
	City centre	*high*	Relation society-environment-building	*medium*	
	Waterfront	*medium*	Social inclusion	*high*	
	Main services	*high*	Social participation	*high*	
Other information					
Economic feasibility	*low*	Political feasibility	*medium*	Investments	*high and private*
Applied materials	Sand, gravel, wood, expanded clay, recycled metal, recycled plastic, cor-ten, iron, steel, aluminium, galvanized steel, fiber-reinforced concrete, gres, flax fibre, wood fibre, laminated glass, low-emissive glass, photochromic glass, plastic materials, glue, additives, panels, plaster, mortar, fireproof paint	Implemented technologies	Shieldings, photovoltaic system, heating and cooling, electric system, ventilation system, exhaust system, glazed facade, photochromic glass, low-emissive glass, laminated glass, vertical brise soleil, panels, offsets, thermal insulation, acoustic insulation, natural ventilation, natural lighting, structural glass facade, double insulation wall, false sealing for installations, thermo-acoustically insulated floor, earthquake resistant foundation, seismic joints, stairs, lift, catwalks, green roof, photovoltaic roof	Security and safety systems	Alarm system, domotic system, cameras, sprinklers, fire escape stairs, escape routes, fireproof doors, open spaces, double height spaces, connection between different floors
S.W.O.T. Analysis					
Strenghts			**Weaknesses**		
Proximity of the disused industrial site to the city center; proximity of the lot to the main urban roads; low level of degradation of the existing; ease of disassembly and disposal of some building components; flexible and spacious covered spaces to accommodate new functions; presence of historic buildings to be enhanced and preserved; architectural and formal singularities; possibility of reuse of existing metal structures			Incompatibility of the industrial conglomerate with the neighbouring city fabric; lack of primary services for the community; low presence of public transport; high and fragmented presence of unused and abandoned contexts; poor maintenance of urban planning; social fragmentation and disgregation; high building density in the lot; poor management of driveway flows and high traffic; prostitution; presence of high voltage pyals and TERNA electric plant		
Opportunities			**Threats**		
Encourage and promote the local scenic and film tradition; training future professional figures in the fields of cinematography, theatrical, illustrative, expressive and musical art; mend the social and physical connections of the STANIC district with the other districts of the city of Bari; include in a peripheral context a modern and attractive educational and cultural centre on a regional scale; increase the number of people within the neighborhood and social relations; increase and strengthen the educational and multidisciplinary offer in the Apulian territory with regard to artistic and scenic subjects; promote policies related to national and local cultural tourism through the programming of artistic, theatrical, singing, dance, musical and film events and workshops; giving new life and vitality to a satellite district of the city of Bari; make architecturally and functionally modern and iconic a suburb through singular formal and architectural solutions			Unnecessary use by the local community of the envisaged functions; overpopulation of the area with respect to the existing buildings; congestion of road traffic; lack of funds for the future maintenance and management of facilities; increase in costs and construction times related to the architectural and compositional complexity of the design solution adopted; estrangement and detachment of the industrial conglomerate transformed by adaptive reuse from the environmental context and the existing urban fabric		
Risks					
Building vulnerability, building incompatibility with context, inadequate services for population, hazards, poor amenities, noise, increasing of project construction times, construction errors,technical constraints, increasing of construction costs, lack of investments, incompatibility of the project with current regulations					

Table 4.5.2-7 Building cataloguing sheet (Former ENEL Power Plant).

5. DCS TESTING: DISCUSSION AND RESULTS

5.1 Structuration of discussion and results

After selecting for each case study of industrial decommission in the city of Bari the most punishable functional and compositional solution of adaptive reuse, through the application of Decision Support Systems (MAVT and SWING Weight Method; O-AHP), and cataloguing all the information that emerged from the analysis of the existing building fabric and master plans, results and discussion are presented. This section provides to the definition and simulation of adaptive reuse strategies in the preliminary design phases, as well as the evaluation of the feasibility (f) and risk entity (r) coefficients and the estimation of recovery and construction parametric costs according to the scenarios hypothesized and described in the building cataloguing sheet. The formulation of innovative industrial regeneration processes, as emerged from the methodology, combines synergistically many techniques and decision-making tools to be consistent on real examples. In addition, the implementation of sequential and automatic procedures based on direct relationships between input data and design criteria and sub-attributes speeds up and simplifies procedures for estimating the effectiveness of adaptive reuse intervention.

In particular, this part of the research expresses the main unique and one-to-one iterations among the components, included in the building recovery table, that most influence the automation and structuring phases of preliminary reuse strategies, the values of the feasibility and risk entity coefficients obtained for the five abandoned industrial contexts, the related flow diagrams of the activities involved in the building transformation process and the table of the average refurbishment and construction costs on the basis of the extrapolated parametric unit costs by regional laws or national price lists. The final part of the chapter consists in the validation of the DCS consistency by comparing the results obtained for each case study with the relative values calculated by the ARP Model and the AdaptSTAR Model.

5.2 Automatic design criteria selection through the building cataloguing sheet

Facilitating the decision-making choices of stakeholders in complex and historical disused design areas does not only mean limiting the field of building transformation scenarios to be adopted on a given industrial context, but having a detailed and exhaustive focus of the components that, during the eight design phases highlighted in the building recovery table, temporarily and physically affect the feasibility of adaptive reuse intervention. A first meticulous synthesis of the elements that come into play in the industrial reuse processes for each hypothesis considered takes place through the compilation of the labels contained in the building cataloguing sheet. This descriptive document provides input data about the existing lot conditions and building conversion project to introduce in the building recovery table sections. However, the criteria and sub-attributes that make up the DCS are manifold and cannot all be defined in the intervention identikit sheet. It is, therefore, necessary to start from the characterization of the key components (Physical, Functional and Social Design Criteria) of the DCS to subsequently develop internal and external relations to the seven main design categories, as well as their unique and one-to-one interactions and connections (ANNEX C-c). In addition, the building cataloguing sheet also incorporates distinctive technological parameters of the proposed reuse solution and the related risks that may occur during adaptation processes.

The innovativeness of the multicriteria analysis proposed lies in its automation process that ensures the formulation and graphic configuration of effective adaptive reuse strategies with the aim to pre-emulate futuristic scenarios of sustainable conversion for the unused peri-urban territory through the insertion of information available

from in situ and monitoring surveys and depending on the architectural-technological solution that users wants to simulate for a specific context.
More specifically, this section frames, on the basis of the data related to the five case studies analysed in the previous chapter, the design parameters and connections most involved in the automatic selection and structuring of the general recovery and re-functionalization strategic adaptive reuse framework. However, before starting this step, it should be remembered that by simply looking at the descriptive panels of the pairwise comparisons between parameters contained in ANNEX C-c (ANNEX C-c), a preliminary identification of the main thematic field promoting connections between sub criteria for the evaluation of industrial reuse policies is provided.
The thematic design field driving the process of automatic selection of building adaptation strategies is in all cases studied the Physical Design Criteria. The dimensional factors, building components obsolescence, context and geographical characteristics intrinsic of the decommissioned industrial site, as well as monitoring, recovery and transformation activities and the compositional and architectural approaches that can be developed influence significantly the other six main DCS topics. Indeed, the structural, material, technological and spatial conditions of the existing involve more or less accentuate refurbishment activities to increase building components life cycle, and, consequently, the related recovery costs and specialized workers in order to guarantee an optimal management and construction of adaptation interventions in total safety. In addition, the proposed adaptive reuse scenarios englobe the creation of new volumes, surfaces and architectural shapes that modify the aesthetic perception inside the lot. As a result, the components related to construction costs vary according to the spatial size of the intervention. Not to be excluded in the evaluation of the strategy are the monetary charges related to the phases of monitoring, extraction, production, transport and assembly of new building components, as well as demolition and disposal costs of unused and obsolete structures.
The spatial and dimensional composition of the areas inside and outside the dismissed productive lot and the information emerged from the analysis of the functional level of degradation of the disused industrial site activate Functional Design Criteria

sub-criteria concerning spatial flexibility, flows management and spaces connectivity. These parameters provide an easy understanding of the site potential to host multiple primary services, satisfying society needs.
Two other physical parameters that develop unique external connections for the formulation of adaptive reuse sustainable and smart approaches refer to the orientation of the industrial building complex and the local weather conditions. In particular, almost all the case studies analysed have exposures of the main facades to the south and north, as well as high sunshine and moderate winds and precipitations. These intrinsic environmental factors prevent the adoption and implementation of façade and roofing technologies to ensure optimal indoor comfort and reuse renewable resources with photovoltaic solutions. However, the more or less advanced technological apparatus affects the plants and construction costs, increases maintenance activities and requires specialized technicians for installing and testing components.
Regarding the cause-and-effect relationships with the social, legal and political aspects, the attributes concerning the monitoring, design, recovery and implementation of the adaptive reuse intervention belonging to the Physical Design Criteria must be confronted with all the aspects summarized in the social context analysis issue, the rules and urban standards in force in order not to compromise the validity and legal effectiveness of the intervention. In addition, the activities attributable to times features (Legal Design Criteria) are closely related to the physical characteristics and the complexity of the recovery and new construction solutions considered in the adaptive reuse project.
The morphological structure of the territory, the level of decay of the existing, the formal options implemented, the preventive recovery activities and the design complexity of the reuse interventions can bring out a multiplicity of risks both during the site monitoring phases, and due to more avant-garde and technological architectural strategies that can compromise the effectiveness of the building conversion intervention.
A small section of the building cataloguing sheet identifies a micro-scope related to the Economic Design Criteria category that describes the public and private funding

obtainable for the selected transformation interventions. The availability of funds favours the introduction of multiple passive and domotic technologies, more performing materials and innovative structural alternatives, increasing the construction quality, indoor and outdoor comfort, the safety and accessibility of places, protecting users' health. At the same time, limited funding can reduce population expectations or foster internal disorganization among stakeholders that do not benefit for the development of sustainable urban regeneration policies. In the context of preliminary design and evaluation of reuse interventions, the relationships between spaces and times are not addressed, since they are dependent on third-party quantitative factors (number of workers, monetary resources, etc.) not mentioned in the DCS.

Another main category treated accurately and extensively in the process of cataloguing disused industrial sites regards the functions that compose the design idea. The services envisaged for each dismissed industrial context are considered on the basis of the current population needs and the accurate analysis on missing amenities in the local context. In most cases analysed, the functions implemented in the building reuse program are compared with the technological and plant attributes proposed in the project. The latter differ according to the intended uses in the adaptive reuse model with the aim of guaranteeing the highest standards of building and environmental quality, safety and security. A further cause-and-effect relationship compares the functional options adopted for each dismissed industry with the social sub-attributes relevant for the evaluation of attractiveness, liveability and spaces usability indicators. However, at the economic level, the definition of specific functional programs allows to estimate demand, supply, job opportunity, possible consumer involved and the intervention profitability parameters. At the same time, if the budgeted functions do not meet the current needs of the community, incompatibilities may emerge within marginal city contexts with a consequent non-use of the building by users.

Adaptive reuse design hypotheses incorporate a multiplicity of technological parameters. The penultimate part of the building cataloguing sheet lists the materials, the main structural, façade and plant technologies and the safety and security systems designed for each master plans proposed, assuming that their application on building envelopes guaranteed medium/high conditions of quality, excellent energy performance and high people safety and protection. In addition, in order to pursue these ambitious objectives, a multiplicity of technical figures specialized in the field of construction, electronics, information technology and engineering must be involved in the processes of building transformation. The co-participation of several technological solutions within the same converted context greatly increases the design, construction and maintenance costs and workmanship times, as well as favours the emergence of technical problems or construction defects, compromising the future buildings performances. Moreover, the implementation of smart and innovative devices in the project must be compliant with current laws and regulations. For this reason, it is necessary to highlight in the industrial conversion strategy the political attributes concerning technical standards, typological data sheets and energy certifications.

The third part that constitutes the building cataloguing sheet encloses the stakeholders who intervene in industrial reuse processes and the users who will use these re-functionalized spaces. More specifically, in lot of the cases covered, the professional figures participate actively in the phases of organization, control, management, design and construction and are involved in multiple transformation steps schematised in the building recovery table. The more complex the design alternative, the more specialized people must actively participate in industrial reuse and re-functionalization processes. This situation could create confusion and disorganization in the sequence and hierarchies of construction processes, prolonging the time envisaged for the complete realization of the intervention. Further data referring to the Social Design Criteria list the primary needs of the local population considered in the projected adaptive reuse scenario and evaluate not only the sub-attributes related to the existing places perception, historic importance and iconicity, but also attractiveness, usability and inclusiveness features that the proposed new architectural master plan achieve.

Legal and Political Design Criteria are not included in the building cataloguing sheet, as all time, political and legislative parameters depend on the categories previously mentioned. However, although the respect of urban standards and rules must be a practice in urban development and regeneration processes, non-carelessness or non-compliance of stakeholders could lead to corruption and incompatibility of the project with current national, regional and municipal laws and to the extension of bureaucratic timeframes for the approval of preliminary, final and executive adaptive reuse projects.

These considerations structure the network of connections between DCS categories and sub-categories in order to estimate the feasibility coefficient (f) of the sustainable transformation intervention developed for the five disused industrial contexts accounted and the relative level of the risk entity (r).

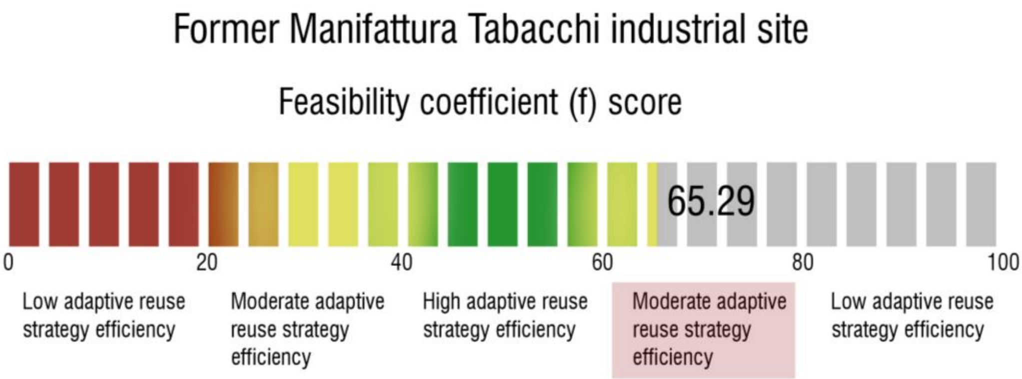
5.3 The DCS final adaptive reuse strategies flowcharts and calculation of feasibility coefficient and risk entity

The use of multicriteria models of choice for the calculation of innovative adaptive reuse solutions in the preliminary design phases allows engineers, architects and stakeholders who want to simulate hypothetical building conversion scenarios to evaluate the feasibility and risk magnitude of the policies affecting building adaptation interventions. The Design Criteria System (DCS) evaluates the selected architectural industrial reuse options, through the sum of the components that come into play in the regeneration process based on the input data contained in the building cataloguing sheet and the cause-and-effect relationships established between categories, attributes and sub-attributes. In addition, the strategic adaptive reuse solution formulated by the proposed multi-attribute radio-centric model is graphically represented in the building recovery table through activities flowchart.

The main goal provides to combine quantitative data for the evaluation of building conversion intervention with explanatory diagrams that synthesise factors and risks, favouring or hindering the real feasibility of the adaptive reuse option in question.

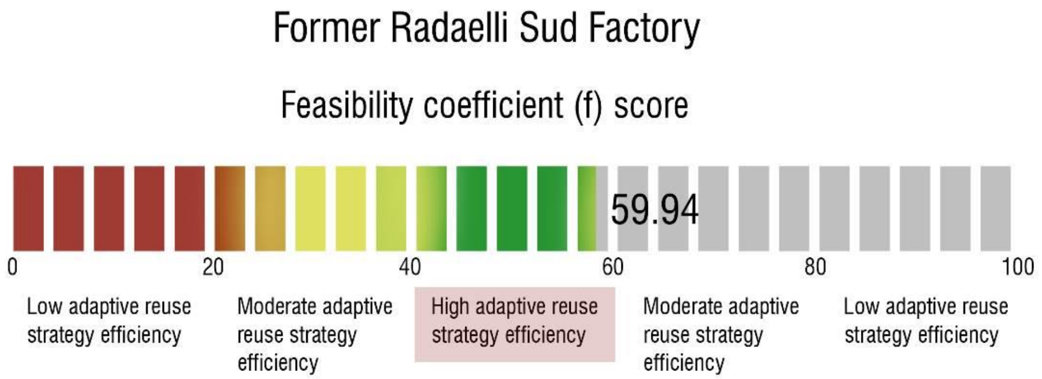
This section tests the consistency and robustness of the DCS architecture, evaluating the five functional and compositional reuse strategies arisen from the results of the applied Decision Support Systems (DSSs). In particular, the process of selecting components took place by implementing firstly the input information of the summary sheets according to case study and project features in the radio-centric system, and, later, identifying the additional evaluation parameters on the basis of internal and external and unique and one-to-one relationships synthesised in the ANNEX C-c tables (ANNEX C-c). The sum of the active components of the DCS ensures to obtain the feasibility coefficient (f) and the risk entity score (r) of the individual adaptive reuse design options for each dismissed industrial context contemplated.

The following graphs show the results obtained from the calculation of each adaptive reuse alternative provided for the disused industrial sites analysed (Figures 5.3-1; 2; 3; 4; 5) and the scores highlighting the greater or lesser presence of uncertainties and risks that may occur during the monitoring, programming and implementation of building refurbishment and conversion phases (Figures 5.3-6; 7; 8; 9; 10).



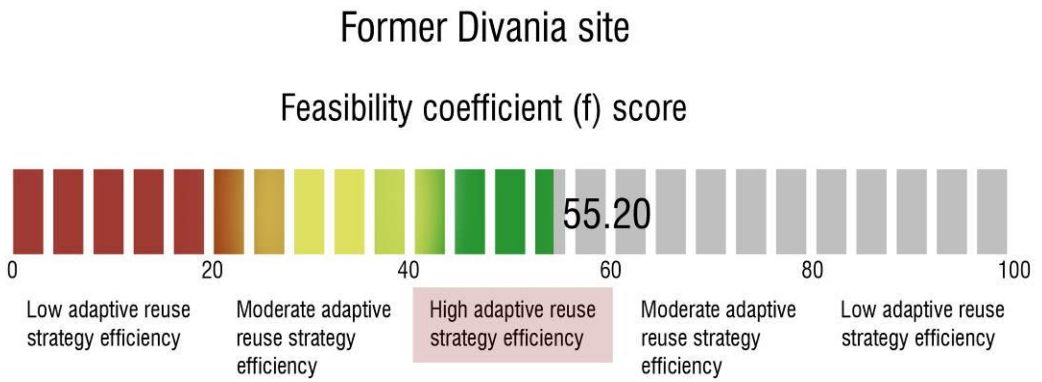
Former Manifattura Tabacchi industrial site								
Physical Design Criteria	Economic Design Criteria	Functional Design Criteria	Technological Design Criteria	Social Design Criteria	Legal Design Criteria	Political Design Criteria	(f)	(r)
11.34	7.57	8.53	10.33	9.67	9.21	8.64	65.29	53.3

Figure 5.3-1 Feasibility coefficient (f) (Former Manifattura Tabacchi industrial site).



Former Radaelli Sud Factory								
Physical Design Criteria	Economic Design Criteria	Functional Design Criteria	Technological Design Criteria	Social Design Criteria	Legal Design Criteria	Political Design Criteria	(f)	(r)
9.08	6.6	7.91	9.99	10.47	8.92	6.97	59.94	40.43

Figure 5.3-2 Feasibility coefficient (f) (Former Radaelli Sud Factory).

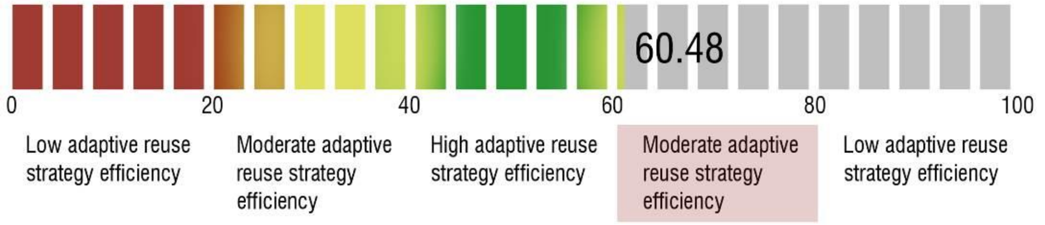


Former Divania site								
Physical Design Criteria	Economic Design Criteria	Functional Design Criteria	Technological Design Criteria	Social Design Criteria	Legal Design Criteria	Political Design Criteria	(f)	(r)
7.65	5.6	6.26	9.83	9.81	8.28	7.77	55.2	25.24

Figure 5.3-3 Feasibility coefficient (f) (Former Divania site).

Former STANIC Refinery

Feasibility coefficient (f) score

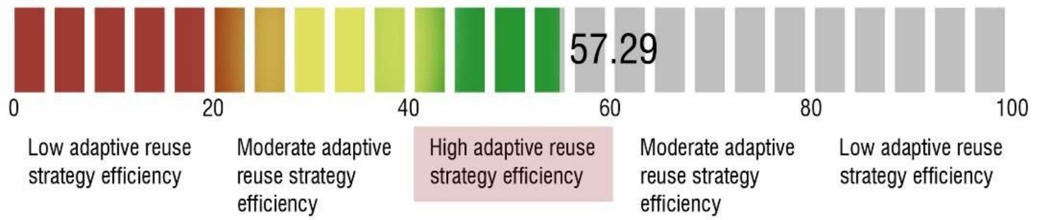


Former STANIC Refinery								
Physical Design Criteria	**Economic Design Criteria**	**Functional Design Criteria**	**Technological Design Criteria**	**Social Design Criteria**	**Legal Design Criteria**	**Political Design Criteria**	**(f)**	**(r)**
9.01	6.92	8.61	9.02	9.76	9.32	7.84	60.48	49.93

Figure 5.3-4 Feasibility coefficient (f) (Former STANIC Refinery).

Former ENEL Power Plant

Feasibility coefficient (f) score

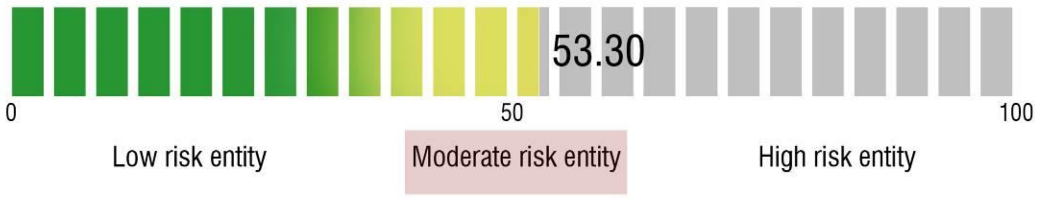


Former ENEL Power Plant								
Physical Design Criteria	**Economic Design Criteria**	**Functional Design Criteria**	**Technological Design Criteria**	**Social Design Criteria**	**Legal Design Criteria**	**Political Design Criteria**	**(f)**	**(r)**
8.79	6.13	7.25	8.76	10.21	9.18	6.97	57.29	52.79

Figure 5.3-5 Feasibility coefficient (f) (Former ENEL Power Plant).

Former Manifattura Tabacchi industrial site

Risk entity (r) score

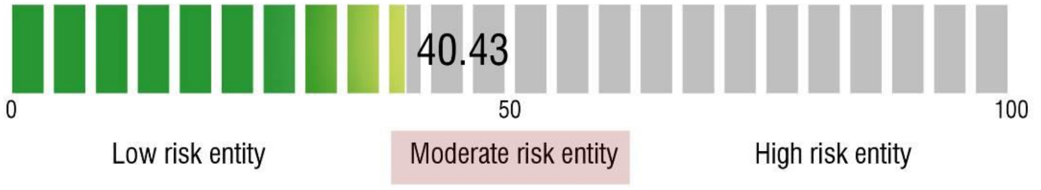


Category	Code	Weight (%)	Attributes	Code	Weight (%)	Sub-attributes	Code	Weight (%)
Risks	H	100.00	Existing building	H1	33.27	Presence of asbestos	H1.1	5.13
						Collapses	H1.2	4.78
						Vandalism	H1.3	2.95
						Inflexible layout	H1.4	3.76
						Building defections	H1.5	3.85
						Spatial constraints	H1.6	3.98
						Building vulnerability	H1.7	4.34
						Building incompatibility with context	H1.8	4.48
			Site	H2	16.12	Inadequate services for population	H2.1	4.00
						Hazards	H2.2	4.63
						Poor amenities	H2.3	3.83
						Noise	H2.4	3.66
			During and after building conversion processes	H3	50.61	Increasing of project and construction times	H3.1	4.22
						Increasing of bureaucratic times	H3.2	4.71
						No respect of rules and corruption	H3.3	4.87
						Construction errors	H3.4	4.95
						Technical constraints	H3.5	4.38
						Increasing of construction costs	H3.6	4.63
						Building disuse by users	H3.7	4.54
						Lack of investments and disorganisation between stakeholders	H3.8	4.96
						Incompatibility of the project with current regulations	H3.9	4.70
						Accidents at work	H3.10	4.15
						Incompatibility of the expected functions towards the actual population needs	H3.11	4.50

Figure 5.3-6 Risk entity coefficient (r) (Former Manifattura Tabacchi industrial site).

Former Radaelli Sud Factory

Risk entity (r) score

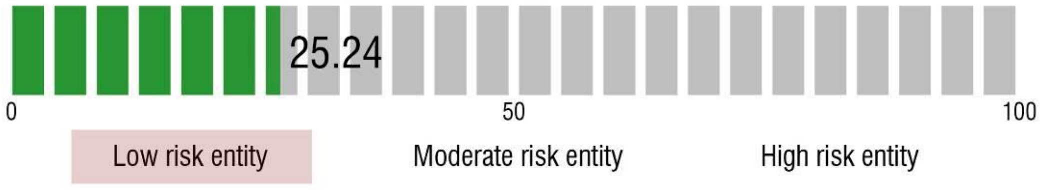


Category	Code	Weight (%)	Attributes	Code	Weight (%)	Sub-attributes	Code	Weight (%)
Risks	H	100.00	Existing building	H1	33.27	Presence of asbestos	H1.1	5.13
						Collapses	H1.2	4.78
						Vandalism	H1.3	2.95
						Inflexible layout	H1.4	3.76
						Building defections	H1.5	3.85
						Spatial constraints	H1.6	3.98
						Building vulnerability	H1.7	4.34
						Building incompatibility with context	H1.8	4.48
			Site	H2	16.12	Inadequate services for population	H2.1	4.00
						Hazards	H2.2	4.63
						Poor amenities	H2.3	3.83
						Noise	H2.4	3.66
			During and after building conversion processes	H3	50.61	Increasing of project and construction times	H3.1	4.22
						Increasing of bureaucratic times	H3.2	4.71
						No respect of rules and corruption	H3.3	4.87
						Construction errors	H3.4	4.95
						Technical constraints	H3.5	4.38
						Increasing of construction costs	H3.6	4.63
						Building disuse by users	H3.7	4.54
						Lack of investments and disorganisation between stakeholders	H3.8	4.96
						Incompatibility of the project with current regulations	H3.9	4.70
						Accidents at work	H3.10	4.15
						Incompatibility of the expected functions towards the actual population needs	H3.11	4.50

Figure 5.3-7 Risk entity coefficient (r) (Former Radaelli Sud Factory).

Former Divania site

Risk entity (r) score



Category	Code	Weight (%)	Attributes	Code	Weight (%)	Sub-attributes	Code	Weight (%)
Risks	H	100.00	Existing building	H1	33.27	Presence of asbestos	H1.1	5.13
						Collapses	H1.2	4.78
						Vandalism	H1.3	2.95
						Inflexible layout	H1.4	3.76
						Building defections	H1.5	3.85
						Spatial constraints	H1.6	3.98
						Building vulnerability	H1.7	4.34
						Building incompatibility with context	H1.8	4.48
			Site	H2	16.12	Inadequate services for population	H2.1	4.00
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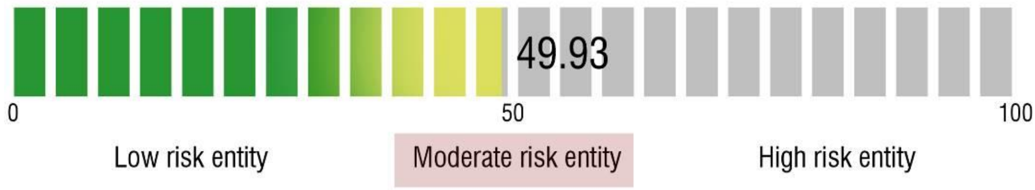
						Construction errors	H3.4	4.95
						Technical constraints	H3.5	4.38
						Increasing of construction costs	H3.6	4.63
						Building disuse by users	H3.7	4.54
						Lack of investments and disorganisation between stakeholders	H3.8	4.96
						Incompatibility of the project with current regulations	H3.9	4.70
						Accidents at work	H3.10	4.15
						Incompatibility of the expected functions towards the actual population needs	H3.11	4.50

Figure 5.3-8 Risk entity coefficient (r) (Former Divania site).

Former STANIC Refinery

Risk entity (r) score



Category	Code	Weight (%)	Attributes	Code	Weight (%)	Sub-attributes	Code	Weight (%)
Risks	H	100.00	Existing building	H1	33.27	Presence of asbestos	H1.1	5.13
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						Vandalism	H1.3	2.95
						Inflexible layout	H1.4	3.76
						Building defections	H1.5	3.85
						Spatial constraints	H1.6	3.98
						Building vulnerability	H1.7	4.34
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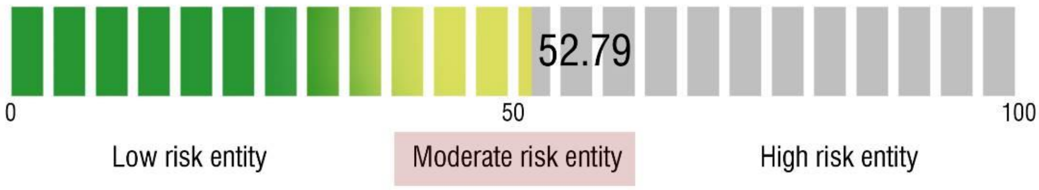
						Increasing of bureaucratic times	H3.2	4.71
						No respect of rules and corruption	H3.3	4.87
						Construction errors	H3.4	4.95
						Technical constraints	H3.5	4.38
						Increasing of construction costs	H3.6	4.63
						Building disuse by users	H3.7	4.54
						Lack of investments and disorganisation between stakeholders	H3.8	4.96
						Incompatibility of the project with current regulations	H3.9	4.70
						Accidents at work	H3.10	4.15
						Incompatibility of the expected functions towards the actual population needs	H3.11	4.50

Figure 5.3-9 Risk entity coefficient (r) (Former STANIC Refinery).

Former ENEL Power Plant

Risk entity (r) score



Category	Code	Weight (%)	Attributes	Code	Weight (%)	Sub-attributes	Code	Weight (%)
Risks	H	100.00	Existing building	H1	33.27	Presence of asbestos	H1.1	5.13
						Collapses	H1.2	4.78
						Vandalism	H1.3	2.95
						Inflexible layout	H1.4	3.76
						Building defections	H1.5	3.85
						Spatial constraints	H1.6	3.98
						Building vulnerability	H1.7	4.34
						Building incompatibility with context	H1.8	4.48
			Site	H2	16.12	Inadequate services for population	H2.1	4.00
						Hazards	H2.2	4.63
						Poor amenities	H2.3	3.83
						Noise	H2.4	3.66
			During and after building conversion processes	H3	50.61	Increasing of project and construction times	H3.1	4.22
						Increasing of bureaucratic times	H3.2	4.71
						No respect of rules and corruption	H3.3	4.87
						Construction errors	H3.4	4.95
						Technical constraints	H3.5	4.38
						Increasing of construction costs	H3.6	4.63
						Building disuse by users	H3.7	4.54
						Lack of investments and disorganisation between stakeholders	H3.8	4.96
						Incompatibility of the project with current regulations	H3.9	4.70
						Accidents at work	H3.10	4.15
						Incompatibility of the expected functions towards the actual population needs	H3.11	4.50

Figure 5.3-10 Risk entity coefficient (r) (Former ENEL Power Plant).

On the basis of the results extrapolated from the calculation of the two coefficients through the application of the DCS, for each case study analysed it is possible to state that:

01) The strategy adopted for the transformation of the former Manifattura Tabacchi industrial site presents a moderate level of adaptive reuse effectiveness and feasibility (65.29/100). However, the high physical obsolescence of existing buildings and context (11.24), as well as the size of the industrial site and the volumetric density raise the feasibility coefficient score. The typological differences of pre-existing warehouses and the high technological quality of the education and didactic functions hypothesized have accentuated even more the complexity of the intervention, obtaining a very high score within the Technological Design Criteria (10.33). Consequently, considering the high level of decay and the multiplicity of technological solutions, the cost factor also affects the effectiveness of the intervention (7.57). All these physical, technological and economic critical issues simulate not only a medium/low level of building resilience, but also the incursion of risks that can completely frustrate the effectiveness of the intervention. The risk entity score assessed by the multicriteria system is moderate (53.3/100). This quantitative value is partially attributable to the situation of degradation and advanced neglect of existing spaces, the vandalism actions on structures, the presence of building defections, collapses and deformed parts, and the total lack of vertical finishes and closures. In addition, the high technological and architectural complexity of the hypothesized option could increase construction costs and refurbishment and adaptation times, as well as structural errors and technical constraints due to a bad components assembly and maintenance works;
02) The adaptive reuse scenario adopted for the former Radaelli Sud Factory falls within the range of efficiency values between 40 and 60 (59.94/100). This means that industrial building adaptation is effective, punishable and achievable. Although the Radaelli Sud complex dates back to the same construction

period as the Manifattura Tabacchi, the existing structures do not present alarming levels of physical degradation and the assumed functional alternative does not incorporate the introduction multiple volumes or particularly complex architectural options. These considerations are confirmed by the partial value obtained from the calculation of the components belonging to the Physical Design Criteria (9.08). On the contrary, the high presence of avant-garde and innovative technologies related to the smart hubs and interactive exhibition functions increases the value inherent the Technological Design Criteria (9.99), as well as the professional figures involved in the processes of realization, testing and maintenance of home automation equipment, passive surveillance and augmented reality tools inserted in the project correspond to a medium/high score of social indicator (Social Design Criteria=10.47). The medium/low level of risk entity score (40.43/100) depends mainly on the lack of attractive services around the industrial lot and by the occurrence of technical problems related to the incompatibility between technological and remote solutions, with a consequent increasing maintenance and repair costs;

03) The transformation of the industrial site of the former Divania site results the most punishable design scenario that can be implemented in reality by the sum of the DCS parameters weight extrapolated. Its final score, in fact, is fully within the maximum effectiveness range of the adaptive reuse intervention (55.20/100), since the low defaced physical conditions of the existing context, the narrow size of the lot, the high spaces adaptability and modularity and restrained volumetric additions decrease significantly the partial values related to the Physical Design Criteria (7.65) and the Economic Design Criteria (5.6). At the same time, Agriculture 4.0 techniques are closely linked to the implementation of smart and innovative technologies and remote greenhouse crop control and monitoring systems. To pursue this objective, the intervention considers a large number of specific avant-garde solutions underlined by the high value of the Technological Design Criteria (9.83) and multiple specialised experts for the management, maintenance and control activities of the

tools englobed in the project identifiable by the partial score obtained from the Social Design Criteria category (9.81). The effectiveness of the intervention is strengthened by a low value of the risk entity (25.24/100) mainly related to the lack of services around the context due to its remoteness from the city center, to spatial lot constraints nestled between smaller industrial warehouses and to any technical problems that may occur during and after the installation of the technological instruments introduced in the prefigured functional hypothesis;

04) The case study of the former STANIC Refinery is the second example that falls within the 60-80 feasibility coefficient range (60.48/100). This fourth industrial complex, like the Manifattura Tabacchi dismissed factory, presents a medium/high level of degradation of the existing structures, the lack of finishes and windows and widespread humidity phenomena. However, this wide context includes limited volumes that reduce the influence of dimensional parameters and architectural compositional options that can be adopted on the existing structures, limiting the partial value related to Physical Design Criteria (9.01). These actual site conditions amplified by the proximity of an area with high hydrogeological risk and the poor surrounding amenities compromise the risk entity level of adaptation interventions (49.93/100). In addition, the design of large new constructions increases the number of functions within the derelict area subjected to conversion actions, but the considerable distances between services reduce its spatial connectivity. These two items affect the partial value of the Functional Design Criteria whose weights sum of the activities considered is equal to 8.61. The risks, associated with the design and construction phases of new volumes on the basis of the design hypothesis developed for the STANIC industrial site, are closely related to an exponential raise of costs and conversion times and by the task of technical and assembly errors of the new structural components characterizing the adaptive reuse alternative;

05) The fifth and final adaptive reuse strategy of the transformation of the ENEL power plant into a film academy is effective in accordance to the value of the feasibility coefficient (f) (57.29/100), but, at the same time, rich of unforeseen events and risks that can occur during the design and implementation phases of the intervention (52.29/100). The value of f obtained for this complex architectural proposal, from the structural and formal point of view of the solutions envisaged, depends a lot by the physical (8.79), technological/material (8.76), social (10.21) and legal (9.18) DCS components. Although the current existing spatial and structural volumes composition is in a good state of preservation, the technological component of pre-existences presents critical conditions. In addition, the architectural and formal dynamism of the modern volumes incorporated in the master plan and the urban green areas entails high quality standards of the materials and technologies to be applied, as well as a specialized and well-organized workforce. The factors added up in the calculation of the risk magnitude of the design adaptive reuse solution not only contemplate the local presence of poor amenities and services, hydrogeological hazards due to the proximity of Lama Lamasinata and numerous high voltage plots, but also negative events that can be accentuated during the construction and static structures testing phases, generating the increase of cost and times, technical and realization errors and disorganization between stakeholders closely connected to the architectural complexity of the proposed compositional scenario.

By comparing the output data obtained from the DCS model about the five adaptive reuse strategies for sheds and disused industrial sites transformation (Table 5.3-1), it can be affirmed that:

a) The urban regeneration scenario of the former Divania industrial site is the most effective between the case studies analysed, also if it corresponds to the disused lot located far from the urban centres. This consideration leads to the conclusion that if the building incorporates useful and innovative functions, wherever it sits, the same can meet the needs of the population and attract future users;

b) On the other hand, the strategy regarding the functional and architectural conversion of the disused industrial site of Manifattura Tabacchi results the least effective case study, since the degradation of existing structures combined with multiple hypothesised services and advanced technologies weighs on economic and physical aspects;

c) Industrial sites suffering by acute physical, functional, technological and plant degradation pathologies lead to greater resource expenditure and increase the risks and ineffectiveness of adaptive reuse intervention. At the same time, disused industrial warehouses with low levels of physical obsolescence and spatial modularity can develop sustainable and innovative urban regeneration policies restraining times and costs;

d) Abandoned extensive and dense industrial complexes cannot achieve feasible refurbishment and site transformation policies, greatly accentuating the recovery and maintenance costs due to the preservation of the main architectural intrinsic components. Moreover, less dense and smaller lots promote interesting reuse solutions that enclose contemporary architectural hypotheses and useful services to the local community;

e) Highly technological solutions participating of enclosures or remote and safety systems may not benefit the effectiveness of adaptive reuse, as they would entail considerable risks and uncertainties during the phases of realization and testing steps;

f) Although the conversion intervention of the ENEL power plant has obtained an optimal score to activate adaptive reuse processes, the too much ostentation and particularization of the compositional and formal aspects does not benefit the actual feasibility of the project, increasing the risk factors related to the production, construction and assembly of the architectural singularities envisaged;

g) The DCS model tested for the evaluation of the five adaptive reuse scenarios results consistent in the calculation of output evaluation coefficients and formulation of strategic and time-defined flow diagrams, intuitive in relation to the selection of design components and the identification of cause-and-effect connections between parameters and effective in the preliminary evaluation of design alternatives, posing as a multi-attribute simulation and decision support tool that facilitates stakeholders' choices in complex industrial dismissed contexts.

Former Manifattura Tabacchi industrial site								
Physical Design Criteria	Economic Design Criteria	Functional Design Criteria	Technological Design Criteria	Social Design Criteria	Legal Design Criteria	Political Design Criteria	(f)	(r)
11.34	7.57	8.53	10.33	9.67	9.21	8.64	65.29	53.3

Former Radaelli Sud Factory								
Physical Design Criteria	Economic Design Criteria	Functional Design Criteria	Technological Design Criteria	Social Design Criteria	Legal Design Criteria	Political Design Criteria	(f)	(r)
9.08	6.6	7.91	9.99	10.47	8.92	6.97	59.94	40.43

Former Divania site								
Physical Design Criteria	Economic Design Criteria	Functional Design Criteria	Technological Design Criteria	Social Design Criteria	Legal Design Criteria	Political Design Criteria	(f)	(r)
7.65	5.6	6.26	9.83	9.81	8.28	7.77	55.2	25.24

Former STANIC Refinery								
Physical Design Criteria	Economic Design Criteria	Functional Design Criteria	Technological Design Criteria	Social Design Criteria	Legal Design Criteria	Political Design Criteria	(f)	(r)
9.01	6.92	8.61	9.02	9.76	9.32	7.84	60.48	49.93

Former ENEL Power Plant								
Physical Design Criteria	Economic Design Criteria	Functional Design Criteria	Technological Design Criteria	Social Design Criteria	Legal Design Criteria	Political Design Criteria	(f)	(r)
8.79	6.13	7.25	8.76	10.21	9.18	6.97	57.29	52.79

Table 5.3-1 Partial and overall values feasibility coefficient (f) and risk entity (r) of the adaptive reuse alternatives for the conversion of marginal dismissed industrial contexts.

ANNEX D (ANNEX D) illustrates the five final flowcharts of adaptive reuse strategies provided for each case of industrial divestment based on the time division of the eight design phases underlined in the building recovery table. To provide a clear and intuitive overview of the active design components extrapolated by the DCS, the main cause-and-effect connections and relationships between categories, attributes and sub-attributes that compose the procedures of sustainable industrial recovery are voluntarily omitted. However, iterations between tasks are reviewable and accurately described in ANNEX C-c (ANNEX C-c).

5.4 Definition of preliminary adaptive reuse construction costs

To consolidate the robustness of the coefficients obtained, this section highlights the costs of each adaptive reuse option considered. The economic values of the five interventions are calculated accounting the listed parametric costs most relevant to the morphological and compositional features of the industrial lots under analysis. In particular, the cost units selected for the economic feasibility assessment of the identified design solutions refer to complex industrial reuse and new construction interventions already carried out or to cost limits related to the development of new envelopes and building refurbishment interventions. These items include not only the basic costs of technical construction, but also the additional costs for unforeseen events, waste disposal, maintenance and monitoring activities and to guarantee high indoor and outdoor environmental quality standards. Based on quantitative information about the recovered and newly built surfaces of each compositional scenario calculated from the information contained in the building cataloguing sheet, the recovery and new construction costs are estimated for each parametric cost index listed. The considerable complexity and innovativeness of the industrial regeneration design alternatives proposed in the research has reduced the choice of parametric costs to eight economic values (two for recovery interventions and six for new construction interventions). The average of the parametric costs highlighted in the Table 5.4-1 (Table 5.4-1), according to the surface values retrieved or added of each adaptive reuse option, quantifies respectively the final recovery and construction costs at the preliminary design stage. The final adaptive reuse solution cost is obtained through the sum of the previous two scores with the costs for the improvement of buildings seismic resistance.

As can be seen from the estimated economic data, the adaptive reuse design and functional solution of the former Manifattura Tabacchi industrial plant is the most expensive one (about 172 million euros).
On the contrary, the industrial conversion scenarios economically punishable by their extent and architectural quality are those adopted for the former Divania site (about 33 million euros) and the former Radaelli factory (about 45 million euros).
Moreover, the obtained costs further strengthen the validity and consistency of the feasibility coefficients (f) formulated by the DCS model and, as stated in the previous paragraphs, it depends on the existing lot and buildings conditions and on the technological, formal and structural hypothesis envisaged in building adaptation projects. These quantitative data favour to assess in good time the economic feasibility of an industrial reuse project.
Quantifying, during preliminary design phase, the cost of industrial recovery and conversion helps stakeholders not only by providing feedback on the cost-effectiveness of the proposed adaptive reuse policies, but also instantly simulating more performing and qualitatively satisfactory options, modifying the spatial and volumetric components at stake or adopting minimally invasive solutions that preserve and retain existing latent resources.

5.5 DCS robustness validation through AdaptSTAR and ARP Models

The process of validating the DCS results consistency and reliability takes place through the application of two multicriteria analysis tools, the ARP Model (Langston et al., 2008; Langston 2012) and the AdaptStar Model (Conejos et al., 2013; Conejos et al., 2015). These two decision-making approaches assess the potential of existing buildings to be subjected to adaptive reuse processes.
In particular, through the ARP Model the existing warehouses research case studies are ranked, extrapolating their adaptive reuse potential at any point of time and predicting factories useful life on the basis of the obsolescence rate per annum obtained from the estimation of the seven categories of decay.

Building refurbishment interventions costs	Basic parametric costs €/sqm	Normalised construction cost index of an industrial warehouse September 2020 - 103.7 (ISTAT)	Normalised parametric costs €/sqm	Former Manifattura Tabacchi industrial site	Former Radaelli Sud Factory	Former Divania site	Former STANIC Refinery	Former ENEL Power Plant
Regional decree n.2081 / 03-11-2009		93.9		**Refurbished surface (sqm)**				
				115350	32635	26546	15128	27860
Basic costs	387.27	109.8	425.22	49049410.76	13877134.98	11287955.42	6432765.37	11846697.74
Building recovery costs to assess sustainability issues	480.22	109.8	527.28	60821927.95	17207833.71	13997216.29	7976715.44	14690064.26
Costs for additional technical conditions	669.98	109.8	735.64	84855847.91	24007547.44	19528247.41	11128732.27	20494875.79
Additional charges	951.37	109.8	1044.60	120495101.39	34090660.03	27730064.69	15802773.25	29102674.68
Building typologies list prices (DEI, 2019)		103.4		**Refurbished surface (sqm)**				
				115350	32635	26546	15128	27860
Renovation of 3 industrial buildings for office use	1762	100.3	1767.29	203856440.10	57675378.61	46914374.16	26735502.61	49236587.96
Renovation and reclamation of existing buildings	839	100.3	841.52	97068985.95	27462907.30	22338910.28	12730469.18	23444663.62
Building construction costs	**Basic parametric costs €/sqm**	**Normalised construction cost index of an industrial warehouse September 2020 - 103.7 (ISTAT)**	**Normalised parametric costs €/sqm**	**Former Manifattura Tabacchi industrial site**	**Former Radaelli Sud Factory**	**Former Divania site**	**Former STANIC Refinery**	**Former ENEL Power Plant**
Regional decree n.2081 / 03-11-2009		93.9		**Added surfaces (sqm)**				
				10600	3964	12217	76850	15504
Basic costs	646.18	109.8	709.51	7520759.78	2812480.36	8668030.40	54525508.43	11000175.44
Building recovery costs to assess sustainability issues	801.26	109.8	879.78	9325704.89	3487461.71	10748314.78	67611360.44	13640163.07
Costs for additional technical conditions	878.8	109.8	964.92	10228177.44	3824952.39	11788456.96	74154286.44	14960156.89
Additional charges	1300.62	109.8	1428.08	15137656.06	5660912.13	17446862.64	109748006.4	22140964.10
Building typologies list prices (DEI, 2019)		103.4		**Added surfaces (sqm)**				
				10600	3964	12217	76850	15504
Shed class 500 - Flat cover	488	100.3	489.46	5188318.40	1940235.30	5979781.69	37615308.40	7588649.856
Shed class 500 - Double slope cover	474	100.3	475.42	5039473.20	1884572.81	5808230.57	36536180.70	7370942.688
Shed class 1600 - Flat cover	393	100.3	394.18	4178297.40	1562525.56	4815684.84	30292656.15	6111351.216
Shed class 1600 - Double slope cove	366	100.3	367.10	3891238.80	1455176.47	4484836.27	28211481.30	5691487.392
Shed class 5000 - Flat cover	353	100.3	354.06	3753025.40	1403489.88	4325538.80	27209434.15	5489330.736
Shed class 5000 - Double slope cove	314	100.3	314.94	3338385.20	1248430.09	3847646.41	24203292.70	4882860.768
Complete industrial complex - Type A	913	100.3	915.74	9706833.40	3629989.40	11187583.36	70374542.15	14197617.46
Complete industrial complex - Type B	1036	100.3	1039.11	11014544.80	4119024.11	12694782.44	79855449.80	16110330.43
Multi-level industrial building	783	100.3	785.35	8324699.40	3113123.44	9594608.73	60354070.65	12176050.9
Complete industrial complex - Type C	752	100.3	754.26	7995113.60	2989870.78	9214745.55	57964573.60	11693985.02
Improvement of seismic resistance	10.75	100.3	10.78	114291.85	42740.84	131726.75	828615.91	167168.00
Final preliminary project refurbishment costs (obtained by the average value of selected costs factors)				162175770.75	40841463.02	20933578.85	21269137.93	34865731.88
Final preliminary project construction costs (obtained by the average value of selected costs factors)				9453873.73	3902583.97	12027716.55	68540584.53	13827628.14
Final adaptive reuse solution cost				**171743936.32**	**44786787.83**	**33093022.14**	**90638338.37**	**48860528.02**

Table 5.4-1 Final adaptive reuse design solution costs of the five dismissed industrial case studies.

The rankings indicate the industrial complexes that have high potential of adaptive re-use, in relation to the embedded physical life that remains after the original useful life has totally vanished.
The AdaptStar Model, on the other hand, quantifies, on the basis of the historical, morphological and architectural reviews carried out on the mentioned marginal industrial contexts and through the evaluation of weighted design parameters, the performances of the abandoned sheds to develop future policies of adaptive reuse, assuming that the building conversion scenarios hypothesized for the five case studies have yet to occur.

5.5.1 Application of the ARP Model

The first tool to verify the validity of the radio-centric model proposed in the research is the ARP Model. This evaluation system quantifies the refurbishment potential of abandoned or disused buildings, estimating the useful life of buildings based on obsolescence criteria and determining the potential of adaptive reuse interventions.

The calculation of the ARP score for the five industrial decommissioned case studies treated takes place through four fundamental steps:

1. Insertion of physical life (L_p) and building age (L_b) data;
2. Assessment of physical, economic, functional, technological, social, legal and political obsolescence score according to the existing warehouses and context conditions. The sum of the selected values corresponds to the obsolescence rate p. a. that allows to estimate building useful life (L_u) (Eq. 5.5.1-1):

$$\text{Useful life}\,(L_u) = \frac{L_p}{\left(1+\sum_{i=1}^{7} O_i\right)^{L_p}} \qquad (5.5.1\text{-}1);$$

3. Calculation of the effective useful life (EL_u), effective building age (EL_b) and effective physical life (EL_p);
4. ARP score estimation through the following equations (Eq. 5.5.1-2; 3):

$$\mathrm{ARP}_{(\mathrm{increasing})} = 100 - \frac{(\mathrm{EL}_u^2/100)}{\mathrm{EL}_u} \times \mathrm{EL}_b \tag{5.5.1-2}$$

If $EL_b \leq EL_u$

$$\mathrm{ARP}_{(\mathrm{decreasing})} = 100 - \frac{(\mathrm{EL}_u^2/100)}{100 - \mathrm{EL}_u} \times (100 - \mathrm{EL}_b) \tag{5.5.1-3}$$

If $EL_b \geq EL_u$.

Tables 5.5.1-1; 2; 3, 4; 5 (Tables 5.5.1-1; 2; 3, 4; 5) and Figures 5.5.1-1; 2; 3, 4; 5 (Figures 5.5.1-1; 2; 3, 4; 5) show the ARP scores and the model concepts of the five dismissed industrial sites accounted in the research.

The obtained results for each case study are explained in the following points:

a) The first case study analysed concerns the disused industrial context of the former Manifattura Tabacchi. Over the years the building has never been renovated or recovered. Its current building age (L_b) is 59 years and the physical life is conservatively estimated at 150 years. The useful life (L_u) of the existing industrial context is determined by discounting the physical life with the expected obsolescence, considering physical, economic, functional, technological, social, legal and political criteria. In particular, the site of Manifattura Tabacchi over the years has never undergone maintenance activities being in a state of high abandonment. For this reason, the score assigned to physical obsolescence (O_1) is equal to 20%. In addition, the disused lot is located in a decentralized position with respect to the main city services and points of attraction and, therefore, receives a 10% reduction for the economic obsolescence (O_2). Such abandoned area incorporates very large and flexible spaces, but, at the same time, could imply medium/high churn costs for functional alterations, and so a reduction of 10% has been assumed for functional obsolescence (O_3). The present plants and technological options that make up the building apparatus do not guarantee high indoor comfort performances, since they are greatly degraded. A value of 10% for technological obsolescence (O_4) has been selected. Although the manufacturing industry is nowadays abandoned, in its productive period it was a profitable production hub for the city, totally privately owned. A 5% reduction is therefore taken for social obsolescence (O_5). Considering the structural and architectural features of the Manifattura Tabacchi, the masonry, partitions and vertical closures present problems of humidity, ejection of the concrete cover and missing parts that reduce the static solidity of the existing components, although it holds discrete formal qualities. A 15% reduction is applied for legal obsolescence (O_6). Moreover, a favourable and positive support by communities and public administration for the regeneration of these areas modify the final obsolescence rate score with a -10% reduction for political criteria (O_7). Using this data in the ARP Model, useful life (L_u) is estimated as 82 years and its ARP score is 49.97% (moderate and increasing). These two quantitative data affirm a good adaptive reuse conversion potential of the Manifattura Tabacchi conglomerate and a fair number of years available (L_u-L_b=23 years) in order to develop and adopt effective strategies of warehouses regeneration;

b) For the former Radaelli Sud Factory, built in 1971, the current building age is 49 years and the physical life is evaluated at 100 years, because this site is more recent than the Manifattura Tabacchi industrial site. For the definition of the useful life, the parameters of physical, technological and legal obsolescence provide lower reductions than in the previous case study and by 10%, 5% and 5% respectively since the intrinsic characteristics of the structural and plant components of the disused industrial lot incorporate medium/low levels of degradation and better thermo-acoustic insulation performance and material quality and durability. At the same time, since no recovery, restoration and preventive maintenance works on the existing structural components have ever been carried out, churn costs for adaptation and transformation could be moderate or high. For this reason, a 10% reduction has been assumed for functional obsolescence. Taking into account the morphological and geographical level, the case study sits away from the city center and established urban fabrics, entailing a 10% reduction for economic obsolescence. Also for the Radaelli Sud factory the reduction of social obsolescence criterion is only 5%, since, during its period of activity the whole company was privately owned and totally used. Finally, the local community and the ASI Consortium managers level of interest, as well as the public administrations economic support through planning incentives is almost neutral for this case study. A reduction of 5% has been applied for political obsolescence. From the calculation of L_u (61 years) and the ARP score (50.93% High and increasing), it must be said that the disused industrial site of Radaelli Sud incorporates high potential for re-functionalization and transformation through adaptive reuse model and the years available to increase the existing warehouses life-cycle without affecting their physical performance are about 12 (Years to useful life). This means that the higher the score obtained by the ARP Model, the fewer years when disused conglomerates embody favourable conditions and performance to implement useful conversion and recovery strategies;

c) The third case study is the most recent of all, since the current building age is 30 years. For this example, the physical life is estimated at 100 years. The industrial site of the former Divania, as described in the related building cataloguing sheet, has medium/low levels of physical and technological degradation, but the presence of external prefabricated panels reduces its material quality. According to the previous statements, reductions of 5% (Physical obsolescence criteria), 5% (Technological obsolescence criteria) and 10% (Legal obsolescence criteria) are allocated respectively. In addition, the industrial site being of largely open design, attraction low churn costs for adaptation and conversion. For this reason, a reduction of 5% has been identified for functional obsolescence.

Former Manifattura Tabacchi industrial site		Former Radaelli Sud Factory	
Physical Life (L_p)	150	Physical Life (L_p)	100
Building Age (L_b)	59	Building Age (L_b)	49
Original construction date	1961	Original construction date	1971
Today's date	2020	Today's date	2020
Obsolescence criteria evaluation		**Obsolescence criteria evaluation**	
Physical (O_1)	0.2	Physical (O_1)	0.1
Economic (O_2)	0.1	Economic (O_2)	0.1
Functional (O_3)	0.1	Functional (O_3)	0.1
Technological (O_4)	0.1	Technological (O_4)	0.05
Social (O_5)	0.05	Social (O_5)	0.05
Legal (O_6)	0.15	Legal (O_6)	0.05
Political (O_7)	-0.1	Political (O_7)	0.05
Total	0.6	Total	0.5
ARP score calculation		**ARP score calculation**	
Obsolescence rate pa	0.004	Obsolescence rate pa	0.005
Useful Life (L_u)	82.42	Useful Life (L_u)	60.73
Years to useful life	23.42	Years to useful life	11.73
Effective building age (EL_b)	39.33	Effective building age (EL_b)	49.00
Effective physical life (EL_p)	100	Effective physical life (EL_p)	100
Effective useful life (EL_u)	54.95	Effective useful life (EL_u)	60.73
ARP score (%)	**49.97**	ARP score (%)	**50.93**
Moderate and increasing		**High and increasing**	
Maximum ARP score (%) (EL_u=EL_b)	69.81	Maximum ARP score (%) (EL_u=EL_b)	63.12

Table 5.5.1-1 (left) ARP score evaluation for the former Manifattura Tabacchi industrial site.
Table 5.5.1-2 (right) ARP score evaluation for the former Radaelli Sud Factory.

The former Divania site would logically receive a 20% reduction for economic obsolescence as it sits completely separated to the heart of Bari central district. Although production has been flourishing in the first fifteen years, nowadays the Divania headquarters is managed directly by the ASI Consortium of Bari/Modugno, as the brand's spokesperson company has failed. A 10% reduction is identified for social obsolescence. In addition, the considerable distances of the disused sheds from the city center and the main attractive points boost unfavourable values about the level of public and local society interest and curiosity for active participation in design processes. According to this consideration a reduction of 15% is selected for political obsolescence. The relative values of useful life (L_u) (50 years) and ARP score (45.33% Moderate and increasing) assume discrete potential of adaptive reuse for this disused production lot, increasing over time, to host new innovative and attractive functions and discrete average times (20 years) in order to develop sustainable design alternatives, preserving the embedded energy and the performances of the existing structures and materials;

d) The data extracted from the calculation of the adaptive reuse potential of the former STANIC Refinery are not very reassuring. Although the industrial site has undergone significant land reclamation actions and has been considered a conservative value of physical life (150 years) in relation to its historical and evolutionary importance in the development of the secondary sector in Bari, the disused industrial context of the STANIC refinery incorporates high levels of physical (20% reduction), technological (15% reduction) and material obsolescence (15% reduction – Legal obsolescence). Such bad conditions ensure the use of considerable economic resources and churn costs due to the advanced state of space neglect (20% reduction – Functional obsolescence). In addition, comparing the values of useful life (68 years) and building actual age (82 years), the STANIC Refinery's optimal potential for adaptive reuse intervention, preserving its performances and quality features, was reached 14 years ago. At the same time, the high but decreasing value obtained by the ARP Model application (65.75% High and decreasing) provides to state that, at present, the physical and qualitative conditions of the existing warehouses worsen from year to year. If conservative and refurbishment interventions of the area are not activated immediately, a piece of contemporary history of the industrial and urban expansionism of Bari may disappear, since the STANIC volumes no longer conforms to guarantee reliable, sustainable and effective adaptive reuse interventions;

Former Divania site		Former STANIC Refinery	
Physical Life (L_p)	100	Physical Life (L_p)	150
Building Age (L_b)	30	Building Age (L_b)	82
Original construction date	1990	Original construction date	1938
Today's date	2020	Today's date	2020
Obsolescence criteria evaluation		**Obsolescence criteria evaluation**	
Physical (O_1)	0.05	Physical (O_1)	0.2
Economic (O_2)	0.2	Economic (O_2)	0.05
Functional (O_3)	0.05	Functional (O_3)	0.2
Technological (O_4)	0.05	Technological (O_4)	0.15
Social (O_5)	0.1	Social (O_5)	0.05
Legal (O_6)	0.1	Legal (O_6)	0.15
Political (O_7)	0.15	Political (O_7)	0
Total	0.7	Total	0.8
ARP score calculation		**ARP score calculation**	
Obsolescence rate pa	0.007	Obsolescence rate pa	0.005
Useful Life (L_u)	49.78	Useful Life (L_u)	67.54
Years to useful life	19.78	Years to useful life	-14.46
Effective building age (EL_b)	30.00	Effective building age (EL_b)	54.67
Effective physical life (EL_p)	100	Effective physical life (EL_p)	100
Effective useful life (EL_u)	49.78	Effective useful life (EL_u)	45.03
ARP score (%)	**45.33**	ARP score (%)	**65.75**
Moderate and increasing		**High and decreasing**	
Maximum ARP score (%) (EL_u=EL_b)	75.22	Maximum ARP score (%) (EL_u=EL_b)	79.72

Table 5.5.1-3 (left) ARP score evaluation for the former Divania site.

Table 5.5.1-4 (right) ARP score evaluation for the former STANIC Refinery.

e) The last industrial context evaluated by the ARP Model concerns the former ENEL thermoelectrical station, built 62 years ago (L_b). The heritage industrial area incorporates architectural and formal characteristics typical of the large production plants of the mid-twentieth century. To preserve the pre-existing iconic singularities, it is estimated a conservatively physical life equal to 150 years. In recent years the disused industrial site has undergone structural and soil reclamation, as well as plant maintenance, so a score of 5% has been chose to represent its physical obsolescence. In addition, the static, technological and material conditions of the warehouses inside the lot are discrete. For this reason, a reduction of 5% has been assumed for technological and legal obsolescence rates. The considerable proximity of the industrial plant to the consolidated fabrics of the city addresses a reduction of only 5% for economic obsolescence criteria.

Former ENEL Power Plant	
Physical Life (L_p)	150
Building Age (L_b)	62
Original construction date	1958
Today's date	2020
Obsolescence criteria evaluation	
Physical (O_1)	0.05
Economic (O_2)	0.05
Functional (O_3)	0.1
Technological (O_4)	0.05
Social (O_5)	0.05
Legal (O_6)	0.05
Political (O_7)	-0.05
Total	0.3
ARP score calculation	
Obsolescence rate pa	0.002
Useful Life (L_u)	111.16
Years to useful life	49.16
Effective building age (EL_b)	41.33
Effective physical life (EL_p)	100
Effective useful life (EL_u)	74.10
ARP score (%)	**25.15**
Moderate and increasing	
Maximum ARP score (%) (EL_u=EL_b)	45.09

Table 5.5.1-5 ARP score evaluation for the former ENEL Power Plant.

Although the site is still owned by ENEL spa (5% reduction – Social obsolescence), the 10% reduction in functional obsolescence is attributable to the high building density that could imply significant churn costs for alterations. The promotion of design competitions for the smart and futuristic reuse of ENEL electric powerplant activates quite favourable and positive public and institutional supports through planning incentives for its adaptive reuse conversion. A reduction of -5% is applied for political obsolescence. The final results of the ARP Model, considering conservative conditions of the historic industrial site, estimate the useful life (Lu) equal to 111 years and the ARP score corresponding to 25.15% (Moderate and increasing). This information provides to emphasize good adaptive reuse potential of existing components and a longer period of time for developing sustainable renovation and re-functionalization operations without affecting the performance and intrinsic architectural values of building historic pre-existences.

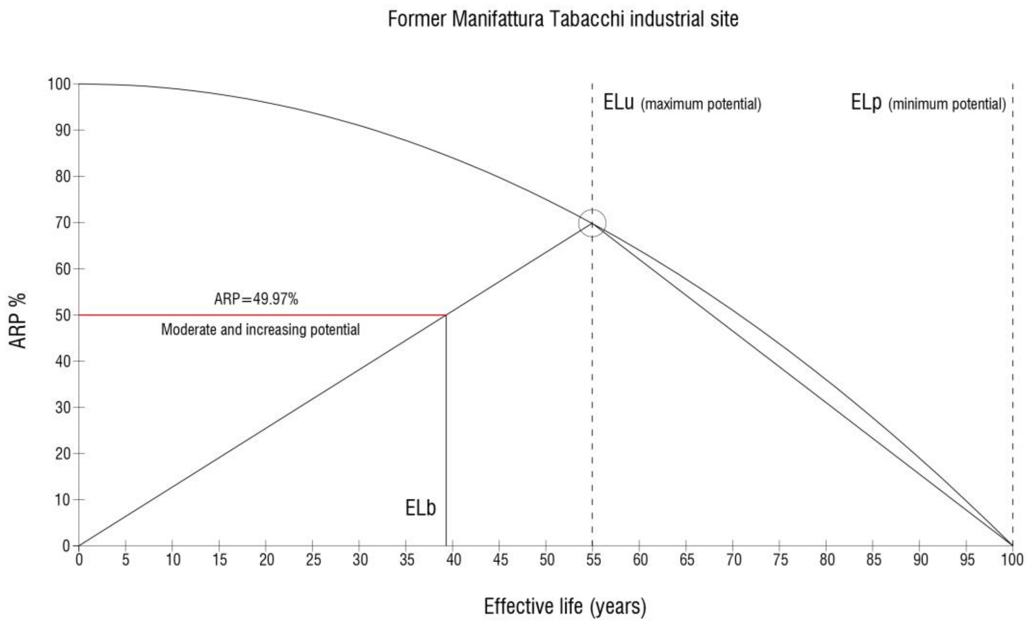


Figure 5.5.1-1 ARP Model concept of adaptive reuse potential for the former Manifattura Tabacchi industrial site.

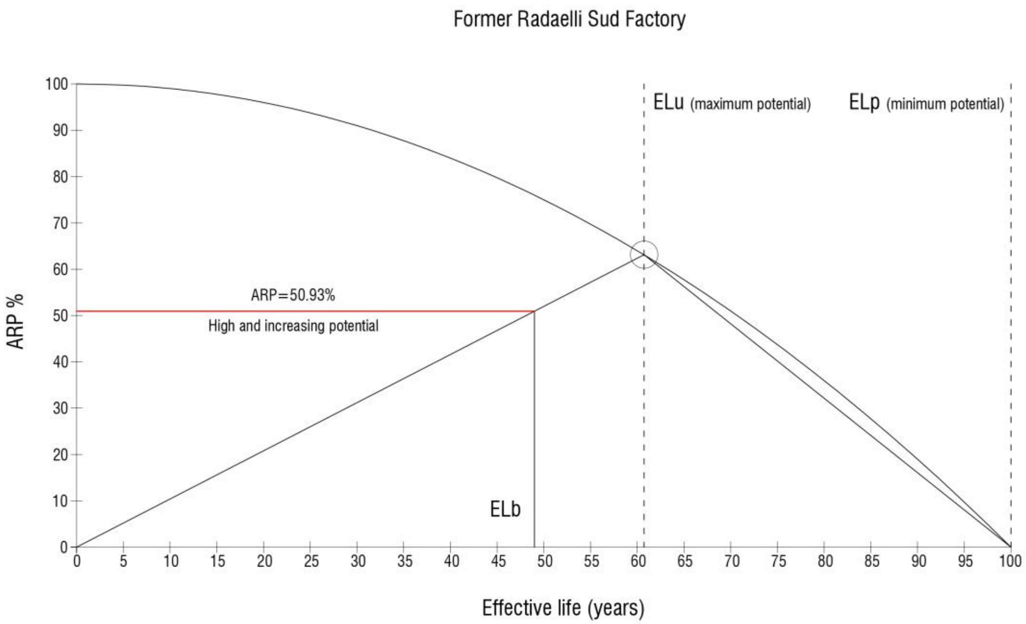


Figure 5.5.1-2 ARP Model concept of adaptive reuse potential for the former Radaelli Sud factory.

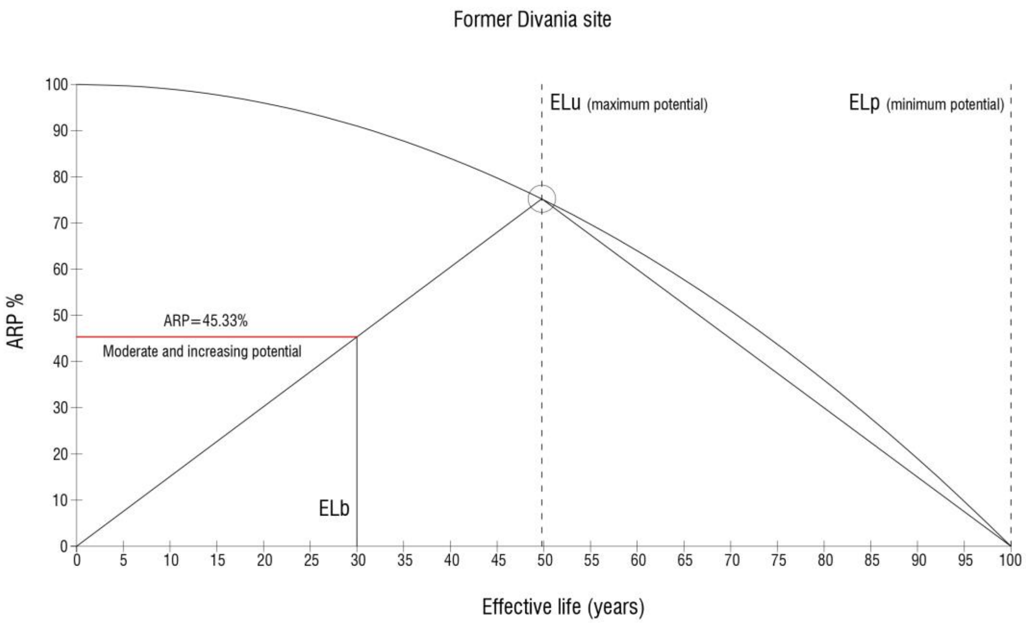


Figure 5.5.1-3 ARP Model concept of adaptive reuse potential for the former Divania site.

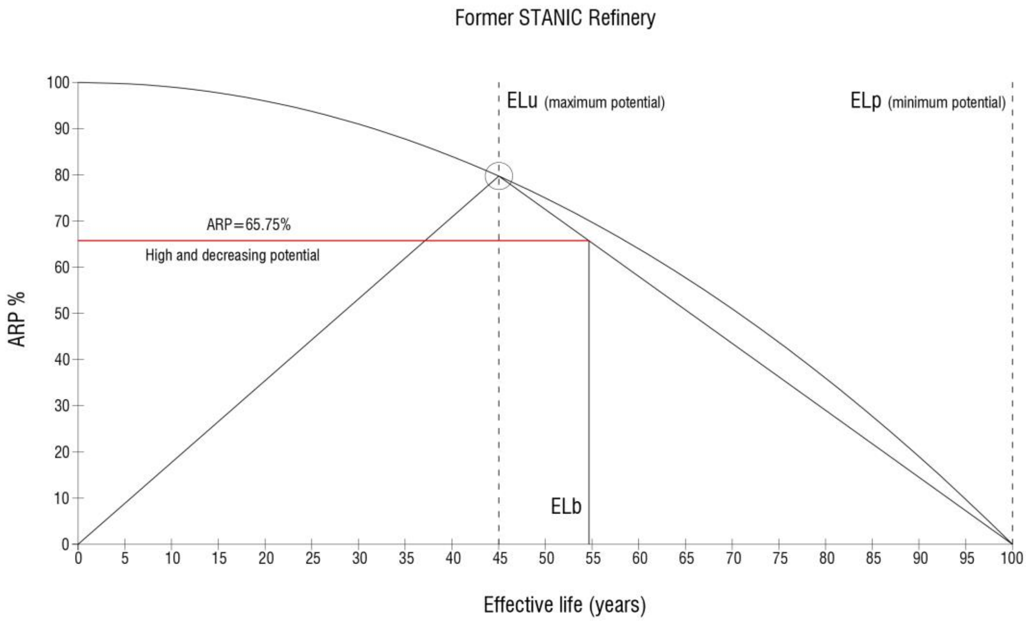


Figure 5.5.1-4 ARP Model concept of adaptive reuse potential for the former STANIC Refinery.

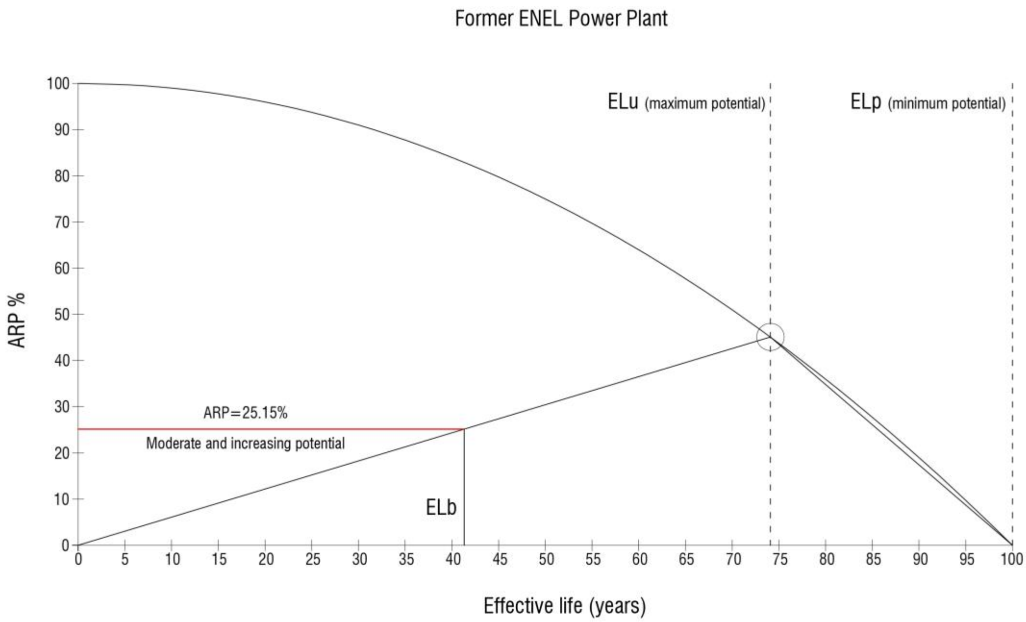


Figure 5.5.1-5 ARP Model concept of adaptive reuse potential for the former ENEL Power Plant.

5.5.2 Application of the AdaptSTAR Model

The second multi-attributes analysis model used to measure the reliability of DCS results is the AdaptStar Model. In particular, this calculation system estimates the reuse potential of a disused building, judging the relevance of the information about the main building components found in the monitoring, thematic maps and in situ analysis phases on the basis of the 26 weighted statements, assuming that the hypothesised adaptive reuse intervention has yet to apply. To give back more consistent AdaptSTAR scores, the answers provided to measure each selected dismissed industrial contexts adaptation potentials for each weighted criterion of the checklist are the result of values comparison and normalisation on the basis of the judgments five people specialized respectively in the topics of sustainable architecture, building recovery, architectural composition, history of construction techniques and adaptive reuse. These experts have expressed opinions according to their knowledge and field of specialisation, selecting values between 1 (strongly disagree) and 5 (strongly agree) to quantify the prevalence of each independent indicator in relationship with the latent conditions of the contexts before reuse interventions. In addition, for assessing accurate outputs scores, respondents take into account primary and secondary sources such as the morphological, physical, logistical and historical information of existing industrial contexts acquired from charts, field observations, site, building inspections and other supporting data, as well as the innovativeness of urban regeneration projects outlined by Decision Support Systems (DSSs).
Tables 5.5.2-1; 2; 3; 4; 5 (Tables 5.5.2-1; 2; 3; 4; 5) show the normalised criteria responses, the AdaptStar's partial values outputs of the seven categories of obsolescence described in the methodology and the total AdaptSTAR score for each specific case study accounted.
The final results illustrate that the two sites with the greatest reuse potential on the basis of the revised information are the ENEL power station (87.33/100 - ***** Stars) and the Radaelli Sud Factory (84.05/100 - ***** Stars). The optimal ranking of the two case studies is mainly due to their iconic architectural and formal components, but also by the presence of high quality and technological standards in the

proposed adaptive reuse solutions. In contrast, the Divania production site achieved the lowest score (74.32/100 - **** Stars), not only because, although the dismissed context incorporates low levels of aesthetic, architectural and structural degradation, it does not contain valuable historical-formal values, but also for its position isolated from the city core.

However, from the comparison of the results extracted from the calculation tables, it is possible to state that the AdaptSTAR Model tends to evaluate positively and with higher scores primarily disused or abandoned buildings that incorporate iconic aesthetic, architectural and formal values that framed a determined historic period, secondly the spatial and qualitative characteristics of existing spaces and, not least in importance, the localising and morphological aspects of the context.

The only limitation of the AdaptSTAR multicriteria estimation Model consists in the partial effectiveness of calculating adaptive reuse potential for newly built abandoned buildings.

Former Manifattura Tabacchi industrial site							
Category	Criterion	1	2	3	4	5	Partial scores
Physical (long life)	Structural Integrity and Foundation	1.12	2.23	3.35	4.46	5.58	12.86
	Material Durability and Workmanship	1.07	2.13	3.2	4.26	5.33	
	Maintainability	1.03	2.07	3.1	4.14	5.17	
Economic (location)	Density and Proximity	0.89	1.79	2.68	3.58	4.47	9.84
	Transport and Accessibility	0.9	1.81	2.71	3.62	4.52	
	Plot Size and Site Plan	0.88	1.76	2.65	3.53	4.41	
Functional (loose fit)	Flexibility and Convertibility	0.68	1.37	2.05	2.74	3.42	12.28
	Disassembly	0.59	1.18	1.78	2.37	2.96	
	Spatial Flow and Atria	0.6	1.2	1.8	2.4	3	
	Structural Grid	0.61	1.21	1.82	2.42	3.03	
	Service Duct and Corridors	0.56	1.13	1.69	2.26	2.82	
Technological (low energy)	Orientation and Solar Access	0.56	1.12	1.68	2.24	2.8	11.34
	Glazing and Shading	0.51	1.02	1.52	2.03	2.54	
	Insulation and Acoustic	0.5	1	1.49	1.99	2.49	
	Natural Lighting and Ventilation	0.53	1.07	1.6	2.14	2.67	
	Energy Rating	0.46	0.92	1.39	1.85	2.31	
	Learn and Obtain Feedback on Building Performance and Usage	0.41	0.82	1.22	1.63	2.04	
Social (sense of place)	Image and History	0.94	1.88	2.81	3.75	4.69	10.47
	Aesthetics and Townscape	1.01	2.02	3.02	4.03	5.04	
	Neighbourhood and Amenities	0.93	1.86	2.78	3.71	4.64	
Legal (quality standard)	Standard of Finish	0.87	1.74	2.62	3.49	4.36	10.7
	Fire protection and Disability Access	0.93	1.86	2.79	3.72	4.65	
	Occupational Health, Indoor Environmental Quality (IEQ), Safety and Secutrity	0.85	1.71	2.56	3.42	4.26	
Political (context)	Ecological Footprint and Conservation	0.81	1.62	2.43	3.24	4.05	10.23
	Community support and Ownership	0.87	1.74	2.61	3.48	4.35	
	Urban Master Plan and Zoning	0.88	1.76	2.63	3.51	4.39	
Total AdaptSTAR score							77.72

Table 5.5.2-1 AdaptSTAR score evaluation for the former Manifattura Tabacchi industrial site.

Former Radaelli Sud Factory							
Category	Criterion	1	2	3	4	5	Partial scores
Physical (long life)	Structural Integrity and Foundation	1.12	2.23	3.35	4.46	5.58	13.89
	Material Durability and Workmanship	1.07	2.13	3.2	4.26	5.33	
	Maintainability	1.03	2.07	3.1	4.14	5.17	
Economic (location)	Density and Proximity	0.89	1.79	2.68	3.58	4.47	9.82
	Transport and Accessibility	0.9	1.81	2.71	3.62	4.52	
	Plot Size and Site Plan	0.88	1.76	2.65	3.53	4.41	
Functional (loose fit)	Flexibility and Convertibility	0.68	1.37	2.05	2.74	3.42	12.2
	Disassembly	0.59	1.18	1.78	2.37	2.96	
	Spatial Flow and Atria	0.6	1.2	1.8	2.4	3	
	Structural Grid	0.61	1.21	1.82	2.42	3.03	
	Service Duct and Corridors	0.56	1.13	1.69	2.26	2.82	
Technological (low energy)	Orientation and Solar Access	0.56	1.12	1.68	2.24	2.8	14.03
	Glazing and Shading	0.51	1.02	1.52	2.03	2.54	
	Insulation and Acoustic	0.5	1	1.49	1.99	2.49	
	Natural Lighting and Ventilation	0.53	1.07	1.6	2.14	2.67	
	Energy Rating	0.46	0.92	1.39	1.85	2.31	
	Learn and Obtain Feedback on Building Performance and Usage	0.41	0.82	1.22	1.63	2.04	
Social (sense of place)	Image and History	0.94	1.88	2.81	3.75	4.69	11.48
	Aesthetics and Townscape	1.01	2.02	3.02	4.03	5.04	
	Neighbourhood and Amenities	0.93	1.86	2.78	3.71	4.64	
Legal (quality standard)	Standard of Finish	0.87	1.74	2.62	3.49	4.36	13.27
	Fire protection and Disability Access	0.93	1.86	2.79	3.72	4.65	
	Occupational Health, Indoor Environmental Quality (IEQ), Safety and Secutrity	0.85	1.71	2.56	3.42	4.26	
Political (context)	Ecological Footprint and Conservation	0.81	1.62	2.43	3.24	4.05	9.36
	Community support and Ownership	0.87	1.74	2.61	3.48	4.35	
	Urban Master Plan and Zoning	0.88	1.76	2.63	3.51	4.39	
Total AdaptSTAR score							84.05

Table 5.5.2-2 AdaptSTAR score evaluation for the former Radaelli Sud Factory.

Former Divania site							
Category	Criterion	1	2	3	4	5	Partial scores
Physical (long life)	Structural Integrity and Foundation	1.12	2.23	3.35	4.46	5.58	13.89
	Material Durability and Workmanship	1.07	2.13	3.2	4.26	5.33	
	Maintainability	1.03	2.07	3.1	4.14	5.17	
Economic (location)	Density and Proximity	0.89	1.79	2.68	3.58	4.47	7.13
	Transport and Accessibility	0.9	1.81	2.71	3.62	4.52	
	Plot Size and Site Plan	0.88	1.76	2.65	3.53	4.41	
Functional (loose fit)	Flexibility and Convertibility	0.68	1.37	2.05	2.74	3.42	12.16
	Disassembly	0.59	1.18	1.78	2.37	2.96	
	Spatial Flow and Atria	0.6	1.2	1.8	2.4	3	
	Structural Grid	0.61	1.21	1.82	2.42	3.03	
	Service Duct and Corridors	0.56	1.13	1.69	2.26	2.82	
Technological (low energy)	Orientation and Solar Access	0.56	1.12	1.68	2.24	2.8	13.38
	Glazing and Shading	0.51	1.02	1.52	2.03	2.54	
	Insulation and Acoustic	0.5	1	1.49	1.99	2.49	
	Natural Lighting and Ventilation	0.53	1.07	1.6	2.14	2.67	
	Energy Rating	0.46	0.92	1.39	1.85	2.31	
	Learn and Obtain Feedback on Building Performance and Usage	0.41	0.82	1.22	1.63	2.04	
Social (sense of place)	Image and History	0.94	1.88	2.81	3.75	4.69	7.67
	Aesthetics and Townscape	1.01	2.02	3.02	4.03	5.04	
	Neighbourhood and Amenities	0.93	1.86	2.78	3.71	4.64	
Legal (quality standard)	Standard of Finish	0.87	1.74	2.62	3.49	4.36	11.47
	Fire protection and Disability Access	0.93	1.86	2.79	3.72	4.65	
	Occupational Health, Indoor Environmental Quality (IEQ), Safety and Secutrity	0.85	1.71	2.56	3.42	4.26	
Political (context)	Ecological Footprint and Conservation	0.81	1.62	2.43	3.24	4.05	8.62
	Community support and Ownership	0.87	1.74	2.61	3.48	4.35	
	Urban Master Plan and Zoning	0.88	1.76	2.63	3.51	4.39	
Total AdaptSTAR score							74.32

Table 5.5.2-3 AdaptSTAR score evaluation for the former Divania site.

Former STANIC Refinery							
Category	Criterion	1	2	3	4	5	Partial scores
Physical (long life)	Structural Integrity and Foundation	1.12	2.23	3.35	4.46	5.58	13.89
	Material Durability and Workmanship	1.07	2.13	3.2	4.26	5.33	
	Maintainability	1.03	2.07	3.1	4.14	5.17	
Economic (location)	Density and Proximity	0.89	1.79	2.68	3.58	4.47	10.73
	Transport and Accessibility	0.9	1.81	2.71	3.62	4.52	
	Plot Size and Site Plan	0.88	1.76	2.65	3.53	4.41	
Functional (loose fit)	Flexibility and Convertibility	0.68	1.37	2.05	2.74	3.42	11
	Disassembly	0.59	1.18	1.78	2.37	2.96	
	Spatial Flow and Atria	0.6	1.2	1.8	2.4	3	
	Structural Grid	0.61	1.21	1.82	2.42	3.03	
	Service Duct and Corridors	0.56	1.13	1.69	2.26	2.82	
Technological (low energy)	Orientation and Solar Access	0.56	1.12	1.68	2.24	2.8	10.91
	Glazing and Shading	0.51	1.02	1.52	2.03	2.54	
	Insulation and Acoustic	0.5	1	1.49	1.99	2.49	
	Natural Lighting and Ventilation	0.53	1.07	1.6	2.14	2.67	
	Energy Rating	0.46	0.92	1.39	1.85	2.31	
	Learn and Obtain Feedback on Building Performance and Usage	0.41	0.82	1.22	1.63	2.04	
Social (sense of place)	Image and History	0.94	1.88	2.81	3.75	4.69	11.41
	Aesthetics and Townscape	1.01	2.02	3.02	4.03	5.04	
	Neighbourhood and Amenities	0.93	1.86	2.78	3.71	4.64	
Legal (quality standard)	Standard of Finish	0.87	1.74	2.62	3.49	4.36	12.4
	Fire protection and Disability Access	0.93	1.86	2.79	3.72	4.65	
	Occupational Health, Indoor Environmental Quality (IEQ), Safety and Secutrity	0.85	1.71	2.56	3.42	4.26	
Political (context)	Ecological Footprint and Conservation	0.81	1.62	2.43	3.24	4.05	10.3
	Community support and Ownership	0.87	1.74	2.61	3.48	4.35	
	Urban Master Plan and Zoning	0.88	1.76	2.63	3.51	4.39	
Total AdaptSTAR score							80.64

Table 5.5.2-4 AdaptSTAR score evaluation for the former STANIC Refinery.

Former ENEL Power Plant							
Category	Criterion	1	2	3	4	5	Partial scores
Physical (long life)	Structural Integrity and Foundation	1.12	2.23	3.35	4.46	5.58	13.89
	Material Durability and Workmanship	1.07	2.13	3.2	4.26	5.33	
	Maintainability	1.03	2.07	3.1	4.14	5.17	
Economic (location)	Density and Proximity	0.89	1.79	2.68	3.58	4.47	11.61
	Transport and Accessibility	0.9	1.81	2.71	3.62	4.52	
	Plot Size and Site Plan	0.88	1.76	2.65	3.53	4.41	
Functional (loose fit)	Flexibility and Convertibility	0.68	1.37	2.05	2.74	3.42	12.28
	Disassembly	0.59	1.18	1.78	2.37	2.96	
	Spatial Flow and Atria	0.6	1.2	1.8	2.4	3	
	Structural Grid	0.61	1.21	1.82	2.42	3.03	
	Service Duct and Corridors	0.56	1.13	1.69	2.26	2.82	
Technological (low energy)	Orientation and Solar Access	0.56	1.12	1.68	2.24	2.8	12.48
	Glazing and Shading	0.51	1.02	1.52	2.03	2.54	
	Insulation and Acoustic	0.5	1	1.49	1.99	2.49	
	Natural Lighting and Ventilation	0.53	1.07	1.6	2.14	2.67	
	Energy Rating	0.46	0.92	1.39	1.85	2.31	
	Learn and Obtain Feedback on Building Performance and Usage	0.41	0.82	1.22	1.63	2.04	
Social (sense of place)	Image and History	0.94	1.88	2.81	3.75	4.69	14.37
	Aesthetics and Townscape	1.01	2.02	3.02	4.03	5.04	
	Neighbourhood and Amenities	0.93	1.86	2.78	3.71	4.64	
Legal (quality standard)	Standard of Finish	0.87	1.74	2.62	3.49	4.36	12.4
	Fire protection and Disability Access	0.93	1.86	2.79	3.72	4.65	
	Occupational Health, Indoor Environmental Quality (IEQ), Safety and Secutrity	0.85	1.71	2.56	3.42	4.26	
Political (context)	Ecological Footprint and Conservation	0.81	1.62	2.43	3.24	4.05	10.3
	Community support and Ownership	0.87	1.74	2.61	3.48	4.35	
	Urban Master Plan and Zoning	0.88	1.76	2.63	3.51	4.39	
Total AdaptSTAR score							87.33

Table 5.5.2-5 AdaptSTAR score evaluation for the former ENEL Power Plant.

5.6 Results comparison with DCS outputs

This last conclusive section compares the feasibility coefficients (f) obtained by the DCS with the ARP and AdaptStar scores. The values summarized in Table 5.6-1 (Table 5.6-1) provide a general and sequential framework of the five derelict industrial case studies analysed and the related design hypotheses implemented, evaluating:

a) The potentials of industrial warehouses to be subjected over time to works of functional and architectural transformation, through adaptive reuse, as well as the years available for providing effective regeneration policies of urban voids without compromising their current performances;
b) The future reusability of disused industrial sheds on the basis of weighted design parameters, estimating the accuracy of the information extracted from a detailed documentation revision of the site historical evolution, the project cartographic surveys and the field inspection activities, without neglecting the objective to be pursued in the proposed adaptive reuse solution;
c) The feasibility of the proposed adaptive reuse scenario, through the structuring of an automated and multicriteria analysis model for the formulation of adaptive reuse strategies that encloses all the parameters affecting industrial conversion processes in all the described design phases. The DCS also relates the synthesized input data for the cataloguing of the building and its design solution with possible other criteria, parameters or risks that may arise in the subsequent management, refurbishment and adaptation steps.

In particular, taking into account the results obtained by the three multicriteria evaluation tools, it is possible to observe that:

1) The disused site of Manifattura Tabacchi generally presents moderate possibilities of re-functionalization and conversion through adaptive reuse. However, the very degraded existing structure and the high-performance characteri-

zation of the proposed building adaptation alternative reduce its effectiveness and feasibility;

2) The site of the former Radaelli Sud plant is the one that can most be subject to regeneration actions with adaptive reuse models. In fact, the values of the feasibility coefficient, the ARP score and the AdaptSTAR score fall within the maximum ranges of the respective calculation tools. This configuration happens when the structural and spatial existing characteristics present little damages and are compliant in terms of spaces flexibility and convertibility to accommodate the functions provided by the project, and the selected reuse solution provides a balanced management of the architectural and technological components, retaining costs;
3) The former Divania industry is the cheapest and most feasible case study of the five studied, but unfavourable logistical conditions and the lack of pre-existing architectural values have greatly reduced the value of the AdaptSTAR score. On the other hand, as regards the potential of existing fabrics to host adaptive reuse interventions, ARP score is moderate and growing over the years;
4) The case study of the former STANIC refinery represents the strategic adaptive reuse option less practicable both for the unfavourable conditions of the existing units, and since the optimal configuration for the adoption of sustainable building conversion interventions on the area dates back more than a decade, although structures incorporate historical architectural characteristics typical of industrial warehouses of the first post-war period. The potential for adaptive reuse of the disused site is high, but the performance of existing structures worsens over the years;
5) The last case study is the most emblematic, since it embeds excellent score of adaptive reuse feasibility coefficient, architectural singularity and formal and material quality of pre-existences, but a moderate level of risk and uncertainty in the design phases accentuated by the complexity of the new volumes hypothesised in the abandoned lot.

The Design Criteria System, therefore, amplifies the theme of adaptive reuse with particular reference to the recovery and transformation of disused industrial construction in metropolitan marginal urban contexts. In addition, the multicriteria radio-centric system and methodology formulated and carefully described in the previous chapters of the research focus the attention on the evaluation of feasible and effective design strategies in order to regenerate marginal urban voids, simulating, in the preliminary design phase, punishable scenarios of building conversion on the basis of the compositional, functional and formal hypotheses thought by each user involved in the decision-making processes.
From the comparison of the results obtained by the three models summarized in the following table (Table 5.6-1), the proposed radio-centric tool could interface excellently with the already patented analysis applications, detailing and strengthening even more the process of estimating the adaptive reuse potentials, not focusing solely on the evaluation of existing latent resources, but measuring different functional and composite scenarios effectiveness for each studied complex industrial contexts.
In conclusion, the DCS, ARP Model and AdaptSTAR Model are complementary innovative and intuitive interfaces that ensure a reliable and pointy analysis of adaptive reuse scenarios and their feasibility and reliability in real complex contexts of industrial divestment.

Former Manifattura Tabacchi industrial site			
DCS Feasibility coefficient (f)	**ARP score**	**AdaptSTAR score**	**Adaptive reuse intervention cost**
65.29	49.97	77.72	171.743.936 euros
Moderate adaptive reuse strategy efficiency	Moderate and increasing	**** Stars	Low economic feasibility
Former Radaelli Sud Factory			
DCS Feasibility coefficient (f)	**ARP score**	**AdaptSTAR score**	**Adaptive reuse intervention cost**
59.94	50.93	84.05	44.786.788 euros
High adaptive reuse strategy efficiency	High and increasing	***** Stars	Medium/High economic feasibility
Former Divania site			
DCS Feasibility coefficient (f)	**ARP score**	**AdaptSTAR score**	**Adaptive reuse intervention cost**
55.2	45.33	74.32	33.093.022 euros
High adaptive reuse strategy efficiency	Moderate and increasing	**** Stars	High economic feasibility
Former STANIC Refinery			
DCS Feasibility coefficient (f)	**ARP score**	**AdaptSTAR score**	**Adaptive reuse intervention cost**
60.48	65.75	80.64	90.638.338 euros
Moderate adaptive reuse strategy efficiency	High and decreasing	***** Stars	Medium economic feasibility
Former ENEL Power Plant			
DCS Feasibility coefficient (f)	**ARP score**	**AdaptSTAR score**	**Adaptive reuse intervention cost**
57.29	25.15	87.33	48.860.528 euros
High adaptive reuse strategy efficiency	Moderate and increasing	***** Stars	Medium/Low economic feasibility

Table 5.6-1 Overview of the final results obtained from the application of the multicriteria models.

6. CONCLUSIONS AND FUTURE DEVELOPMENTS

This thesis proposes an innovative and intuitive multicriteria model methodology integrated with the application of Decision Support Systems (DSSs) for the selection and evaluation of feasible adaptive reuse strategies to convert dismissed historic and modern industrial contexts. The approach englobes sequential operations and estimation steps belonging to different but complementary interdisciplinary topics that enclose optimization processes, decision-making models, multicriteria analysis, sustainable architecture, building refurbishment actions and urban regeneration.
The main interesting and avant-garde features of the presented work can be summarised in five points: a) the application of multicriteria analysis tools and Decision Support Systems for the selection of adaptive reuse design solutions; b) accurate classification and description of the intrinsic characteristics of disused industrial sites and reuse scenarios hypothesized by compiling the building cataloguing sheet; c) the Design Criteria System for the management of components hierarchies according to seven main thematic categories; d) automatic selection of adaptive reuse strategies on the basis of building cataloguing sheet input data and DCS components relationships outlined in the building recovery table; e) DCS testing on five real dismissed historic and modern factories in Bari to measure the feasibility coefficient (f) and the risk entity (r) of the proposed adaptive reuse hypothesis.

Each of these principal phases of the research has been accurately and specifically defined and studied in the previous sections and the main findings are underlined below:

a) The two DSSs applied (MAVT + SWING Weight Method and O-AHP) are particularly effective for identifying the best scenario of refurbishment and industrial transformation for each disused context studied. Moreover, all the steps that facilitate and shrink the decision-making choices of stakeholders, as well as the characterization of performance matrices for the final ranking of the proposed design reuse alternatives on the basis of quantitative and qualitative parameters and direct comparison with experts in the sector have been described and mathematically specified. In particular, the O-AHP methodology ensures to simplify stakeholders' decisions in complex regeneration and transformation processes and to obtain consistent and reliable rankings and weights even if a large number of design criteria and comparisons must be evaluated.
b) The processes of classification and description of the abandoned industrial contexts actual physical and environmental conditions and the related adaptive reuse interventions that emerged from the application of the DSS pursue a dual objective. The first, archival and documentary, concerns the possibility of creating a database of latent industrial resources in the territory to promote future policies of sustainable recovery and development of the city's suburbs, filled the urban voids produced by uncontrolled urban sprawl processes. This operation is effective if in conjunction with the monitoring and inspection in situ activities and review of the site historical documentation, the user explains the physical, functional and social components, the material and technological peculiarities of the adaptive reuse scenario thought and the linked problems, risks and opportunities through S.W.O.T. analysis. The second application objective consists of matching the data summarized in the building cataloguing sheet with the input information to be introduced in the DCS structure and in the building recovery table for the automatic formulation of the adaptive reuse strategy. This approach allows to reduce the disputes between experts who incur in the decision-making processes, reducing time and uncertainties. In addition, such proposed choice instrument favours the indi-

vidual user to evaluate, independently of the other stakeholders involved, his strategic adaptive reuse and transformation hypothesis through a rapid compilation of the descriptive sections related to the project main physical, functional and technological features.

c) Input data represents only a small portion of the attributes and sub-attributes contained in the DCS. The Design Criteria System structuring is one of the key points of the research. This original and unique radio-centric model of multicriteria tool ensures experts to manage a considerable amount of categories and parameters that can influence adaptive reuse processes. In addition, considering the system, the DCS illustrates, divides and encodes the components identified by the existing literature about the theme of adaptive reuse in a hierarchical order that, starting from the center of the diagram with the highlighting of seven main thematic categories, frames attributes, sub-attributes 1, sub-attributes 2 and activities respectively. The features contained in the model are not only listed and sorted into the different thematic categories, but each of them is catalogued and indexed with an ID code and a weight. The DCS components weighting phase takes place through 161 well-structured online interviews with experts in the field of building recovery and adaptation, architecture, urban planning and sustainable construction and a subsequent normalization of the responses obtained. The main benefits of the resulting approach are the simplification of the decision-making operations in case of complex adaptive reuse conversion processes on dismissed industrial and wide peripheral contexts through the implementation of an user friendly and intuitive tool of managing design features and parameters, and the determination of the feasibility coefficient (f) and the risk entity (r) obtained by the sum respectively of design components that intervene and affect the building adaptation intervention and of the morphological, technological and functional constraints arisen by structural surveys of the existing warehouses architecture and project complexity. The two numerical outputs extrapolated from the multicriteria system estimate the effectiveness of the proposed building regeneration strategy, but at the same time notify the level of uncertainty and criticalities of the architectural and functional option examined on the basis of the existing built elements physical conditions and the formal and technological complexity foreseen by the project.

d) In order to enable users a quick and consistent preliminary design assessment of the building conversion intervention, part of the research focused on identifying the cause-and-effect relationships generated between DCS criteria and attributes. In particular, the proposed methodology provides for the development of an automatic selection process that correlates the building cataloguing sheet input data with the additional components that can affect the adaptation strategy. All the DCS items are well organized and juxtaposed in the building recovery table according to the eight main design phases underlined. In addition, 36 thematic tables, of which 28 with pairwise comparisons between categories, define all the internal and external relations, and the unique and one-to-one cause-and-effect connections that can occur in the phases of monitoring, design and implementation of the building adaptation intervention. The final result provides to the composition of schematic flow diagrams, resuming the DCS macro and micro-scopes that intervene in a specific site conversion process of industrial decommissioning and displaying the adaptive reuse strategic framework obtained by the proposed multicriteria tool.

e) A DCS testing procedures on real dismissed industrial case studies is performed in order to quantify its robustness and usability to future users. More specifically, on the basis of the DSS ranking methodology to classify design solutions, the DCS is applied on five disused and marginal industrial contexts in Bari (3 of these located in the ASI Bari/Modugno Consortium) with different sizes and level of physical, functional and technological obsolescence. The results reveal the effectiveness of the proposed multi-attributes choice system with regard to the automatic selection of influential components in the building conversion process, although it was done manually for these case studies.

> The scores extrapolated from the sum of the parameters involved for each individual example mentioned in the research highlight how the physical conditions of industrial places, the lot extension and the accentuated functional, architectural and technological characterization of the design alternatives may not ensure optimal and effective adaptive reuse policies. The calculation of the final intervention costs by parametric analysis amplifies and integrates the data framework available for the preliminary evaluation of future regeneration and urban regeneration strategies. The economic monetary values estimated for each case study reflect the DCS feasibility coefficient (f) and risk entity (r) scores and strengthen the considerations stated above, reinforcing the level of reliability and consistency of the output data extracted from the automated radio-centric system implemented, as well as its future applicability in complex real industrial divestment contexts.

The resulting DCS performs an automatic formulation and evaluation of feasible and punishable adaptive reuse strategies for dismissed warehouses conversions, helping stakeholders' decisions in complex situations. This intuitive and interesting multicriteria management tool can be used by experts interested in the preliminarily estimation of hypothesised functional and architectural conversion scenarios efficiency, providing a detailed and complete overview of the design components involved and the relative cause-and-effect relationships, and perceiving specific reuse objectives. Flowcharts and thematic maps are also developed to share the adaptive reuse strategy with all the selected features temporally scanned in the eight design steps underlined in the building recovery table. It is worth noting that the implemented methodology is applied specifically to dismissed industrial buildings. However, the same tool can be used to evaluate the adaptive reuse feasibility and uncertainty of other abandoned and decommissioned building typologies, extending the DCS effectiveness in multiple design and construction fields. In addition, the radio-centric structure can be easily modified and improved with the insertion of subcategories and parameters by adopting the following procedures: i) organization of the new components to be in-

cluded in the hierarchical structure of the DCS; ii) assessment of parameters influence through experts interviews; iii) normalization of the results obtained and subsequent revision of the DCS features weights.
To verify the validity of the proposed multicriteria choice model and the f and r coefficients robustness, the ARP Model and AdaptSTAR Model are applied to measure the adaptive reuse potentials of the five disused industrial plants. The results obtained from the two analytic approaches illustrate that DCS contributes to an accurate evaluation not only of the current and intrinsic characteristics of the context favourable to develop adaptive reuse interventions, but also of the conversion project effectiveness hypothesized for a disused industrial conglomerate. In addition, the risk entity score allows to highlight alert situation that can decrease adaptive reuse scenarios potentials and effectiveness. The same helps users and developers in the preliminary design phase to make improvements or corrections of the designed compositional and functional alternative, simulating any other more performing and punishable options.
In conclusion, the Design Criteria System enlarges the sphere of available applications for the evaluation of adaptive reuse interventions potentials by correlating the descriptive parameters related to the intrinsic conditions of the disused industrial site with the possible sustainable and innovative design solutions envisaged. Indeed, such model can be compared to a multi-variable and exhaustive analysis tool complementary to the already patented ARP Model and AdaptSTAR Model, since it provides interesting information, at the preliminary design stage, regarding future building adaptation scenarios. These three interesting applications, if used sequentially, provide users a detailed picture of disused production sites adaptability and flexibility to host new services and shape alterations, starting from the estimation of adaptive reuse potentials, up to the schematization of the compositional and functional strategy to be pursued and the evaluation of its economic and design feasibility on the basis of the design scenario risk entity.
Future research implementations will be aimed at the creation of a virtual platform (V.A.R.M. Model - Virtual Adaptive Reuse Multicriteria Model) of data cataloguing and adaptive reuse strategies digital formulation. The application will constitute a Decision

Support System (DSS) that manages the data obtained from the study of abandoned industrial areas and processes them according to the needs of stakeholders and the intrinsic characteristics of the building, formulating innovative and intuitive reuse strategies. This digital analysis tool will allow to visualize preliminary refurbishment and design costs and strategic flowcharts, based on the DCS components that intervene in each construction conversion procedure, rationed in the eight main design steps. The proposed methodology could be extended to evaluate adaptive reuse projects on other abandoned construction typologies and on worldwide dismissed sites.
The development of this thematic and emerging field aims to deepen the topic of adaptive reuse with regard to abandoned industries sustainable regeneration, creating an app easily usable by users and promoting actions for the recovery and regeneration of urban voids present in the marginal tissues of contemporary cities. The implementation of a well-structured methodology and application refutes the thesis of some scholars who minimize the reintegration into the urban context of the disused existing industrial contexts, preferring the demolish and re-built option for the introduction of new incompatible volumes. This study would provide to make the population aware of the economic, social, environmental, functional and aesthetic advantages of refurbishment and sustainable regeneration action on existing derelict sheds, projecting the city towards a modern conception of space, more inclusive and liveable. The main objective pursued in the proposed methodology consists in defining guidelines for innovative and effective adaptive reuse policies, for the organization of feasible and smart building regeneration and community integration interventions, developing environmental reclamation and re-configuration activities to achieve a contemporary and futuristic metropolis vision, through the enhancement of latent and dismissed local resources. It represents the starting point for activating dynamic collaborations with the municipal administration for the promotion of peripheral industrial assets sustainable reuse interventions, through integrated participative programmes that meet the current population needs, consolidate the city-society-environment connections and reduce realization times and costs, towards the most complete expression of a civil society projected to the future.

ANNEX A

(List of worldwide adaptive reuse examples and functional-morphological data)

Building name	City	Conversion years	Nation	Architectural studio	N.	(S) Historic (NS) Not Historic	Main Functions	Distance (km)	Surfaces (sqm)
Foundation Hotel	Detroit	2013 - 2017	USA	McIntosh Poris, Simeone Deary Design Group	1	S	Residential, commercial, sporty, social spaces	1	8.733
Seaholm District	Austin	2013 - 2016	USA	STG design	1	S	Cultural, residential, commercial, offices, social spaces	1.7	18.581
Steel Yard	Providence	2001 - 2010	USA	Klopfer Martin Design Group	1	S	Cultural, residential, education	2.8	14.164
Wonder Bread Factory	Washington DC	2000 - 2013	USA	R2L:Architects	1	S	Commercial	7	9.290
The goat farm arts center	Atlanta	2010-2012	USA	Hallister Development	1	S	Cultural, sporty, education	8	48.563
The green Building	Louisville	2008 - 2009	USA	FER Studio	1	S	Cultural, commercial, offices, education	2.5	945
Seattle gas works park	Seattle	1962 - 1975	USA	Richard Haag Associates con Douglas Tuma, Stephen G. Ray, Kenichi Nakano	1	S	Spaces for fun, social spaces	8.8	80.000
Hughes Warehouse	San Antonio	2012	USA	Overland Partners	1	S	Offices	3	2.120
Boston's Commonwealth Pier	Boston	2017 - 2020	USA	Schmidt Hammer Lassen Architects	1	S	Cultural, commercial, offices, social spaces	2	68.500
10 Jay Street offices	New York	2019	USA	ODA New York	1	S	Offices	2.9	21.367
MASS MoCA	North Adams	1999	USA	Bruner/Cott & Associates	1	S	Cultural, education	0.5	12.478
ATX Factory	Austin	2017	USA	Mark Odom Studio	1	NS	Commercial, offices, sporty, social spaces	5.5	9.000
Greater goods coffee	Austin	2018	USA	Michael Hsu Office of Architecture	1	NS	Commercial	3.4	532
Fort Mason Center for Arts and Culture	San Francisco	2017	USA	Leddy Maytum Stacy Architects	1	S	Cultural, education	4.1	6.505
Wards Cove Marina Warehouse	Seattle	2009	USA	atelierjones	1	NS	Offices	5.2	1.845
BO Bartlett Center	Columbus	2017	USA	Olson Kundig	1	NS	Cultural, education	0.7	1.208
Empire stores	New York	2017	USA	S9 Architecture	1	S	Cultural, commercial, offices, social spaces	3.6	41.807
Westland distillery	Seattle	2013	USA	Urbanadd	1	S	Cultural, commercial	3.5	1.210
Santa Monica animation studio	Santa Monica	2012	USA	Gwynne Pugh Urban Studio	1	S	Offices	0.8	1.580
Blue school middle school	New York	2017	USA	PellOverton Architects	1	NS	Education, spaces for childrens	1.9	1.100
Yarn Works	Fitchburg	2017	USA	The Architectural Team	1	S	Residential	2.2	16.955
Urban outfitters corporate Campus URBN Corporate Campus	Philadelphia	2006 - 2013	USA	MSR Design	1	S	Cultural, offices, education	8	43.020
Cotton gin at the Co-op District	Hutto	2015	USA	Antenora Architects	1	NS	Cultural, spaces for fun, social spaces	0.8	6.500
Rosie the Riveter Visitor Center	Richmond	2011	USA	Marcy Wong Donn Logan Architects	1	S	Cultural	5.2	1.158
Google L.A. office	Los Angeles	2019	USA	ZGF architects	1	S	Offices	28.1	41.807
ProMedica Headquarters	Toledo	2007 - 2009	USA	HKS Architects	1	S	Offices, spaces for health care	1	23.226
High Line	New York	2009 - 2014	USA	Diller Scofidio + Renfro, James Corner Field Operations, Piet Oudolf	1	S	Social spaces	5.1	25.000
The capital's new food chain	Brookland	2012 - 2017	USA	EDENS	1	NS	Commercial, offices	4.2	1.858
University of Minnesota, Morris Welcome Center	Morris	2009	USA	MSR Design	1	S	Cultural, education	1.9	1.738
Mill City Museum	Minneapolis	1991 - 2017	USA	MSR Design	1	S	Cultural	1	11.613
McAllen Main Library	McAllen	2011	USA	MSR Design	1	NS	Cultural, offices, education, spaces for childrens	5.9	11.613
Atrium Lofts	Wausau	2016	USA	MSR Design	1	S	Residential, commercial	3	3.541
Nabisco factory	Pittsburgh	2007 - 2010	USA	Strada Architects	1	S	Commercial, offices	8.6	18.581
Chicago Sustainable Manufacturing Center	Chicago	2002 - 2007	USA	John Edel	1	NS	Commercial, offices	9.3	8.686
Packard building	Detroit	2014 - 2017	USA	Nadau Lavergne	1	S	Cultural, residential, commercial, sporty, social spaces	8.4	371.700
Brooklyn Bridge Park	New York	2003 - 2018	USA	Michael Van Valkenburgh Associates	1	NS	Sporty, spaces for fun, social spaces, spaces for childrens	4.7	344.000
St Ann's Warehouse	Brooklyn	2015	USA	Marvel Architects	1	S	Cultural, offices	3.2	2.370
New Lab	Brooklyn	2016	USA	Marvel Architects	1	S	Cultural, offices, social spaces	4.1	7.804
SteelStacks Arts & Cultural Campus	Bethlehem	2009 - 2015	USA	Metcalfe Architecture and Design of Philadelphia and Art Guild of West Deptford	1	S	Cultural, Sporty, education, spaces for fun, social space, spaces for childrens	3.2	38.445

Lowe Campbell Ewald's Detroit offices	Detroit	2014	USA	McIntosh Poris Associates and Neumann/Smith Architecture	1	S	Offices	1.4	11.335
The Factory at Corktown	Detroit	2016 - 2018	USA	McIntosh Poris Associates and Neumann/Smith Architecture	1	S	Offices	1.2	4.181
The Assembly	Detroit	2016 - 2019	USA	McIntosh Poris Associates and Neumann/Smith Architecture	1	S	Cultural, residential, commercial, offices	2.1	14.865
Ford assembly building	Richmond	2009	USA	Marcy Wong Donn Logan Architects	1	S	Cultural, commercial, office, education, social spaces	5.3	51.000
Concrete plant park	New York	1999 - 2009	USA	NYC Department of Parks and Recreation	1	NS	Sporty, spaces for fun, social spaces, spaces for childrens	23.1	29.907
SILO point	Baltimore	2010	USA	Parameter Inc	1	S	Residential, commercial, offices, spaces for fun	5	92.903
UPCycle Offices	Austin	2018	USA	Gensler	1	NS	Offices	3.4	7.591
355 11th Street	San Francisco	2008	USA	Aidlin Darling Design	1	NS	Commercial, offices	1.3	1.301
Jaegersborg Water Tower	Copenhagen	2004	DENMARK	Dorte Mandrup Arkitekter	2	NS	Residential, education	11.9	5.370
The Silo	Copenhagen	2013 - 2017	DENMARK	COBE	2	NS	Residential	4.9	10.000
Gemini Residence (Frosilos)	Copenhagen	2003 - 2005	DENMARK	MVRDV, Rotterdam con Jensen, Jorgensen, Wohlfeldt Arkitekter A/S	2	NS	Residential	2.6	10.700
Portland Towers	Copenhagen	2013	DENMARK	FKN Gruppe, Arup	2	NS	Cultural, commercial, offices	5	14.000
Copenhill / Amager Bakke	Copenhagen	2012 - 2019	DENMARK	BIG	2	NS	Cultural, commercial, sporty, spaces for fun	4.6	41.000
Danish National Maritime Museum	Helsingor	2013	DENMARK	BIG	2	NS	Cultural, commercial	2.4	17.500
Roskilde Festival Folk High School	Roskilde	2019	DENMARK	COBE, MVRDV	2	NS	Education, social spaces	3	5.578
Residential building refurbishment	Venice	2015	ITALY	Studio Macola	3	S	Residential	9	3.950
Technopole for Industrial Research Shed n. 19	Reggio Emilia	2014	ITALY	Andrea Oliva Architetto	3	S	Cultural, education	5.4	3.600
Factory in Lumezzane reuse	Lumezzane	2017	ITALY	Luigi Serboli, Pierangelo Scaroni	3	S	Offices	3.4	8.831
Casalgrande old house	Casalgrande	2011	ITALY	Kengo Kuma & Associates	3	S	Cultural, offices	2.7	572
Auditorium Paganini	Parma	1999 - 2001	ITALY	Renzo Piano Building Workshop	3	S	Cultural	5.6	2.000
Lingotto	Turin	1985 - 2005	ITALY	Renzo Piano Building Workshop	3	S	Cultural, commercial, offices, sporty, spaces for fun, social spaces	8.4	236.000
Ex Mattatoio di Testaccio, Roma tre	Rome	2000 - 2017	ITALY	Insula architettura e ingegneria - Eugenio Cipollone, Paolo Orsini, Roberto Lorenzotti	3	S	Cultural, commercial, education, social spaces	5.8	25.000
Prada Foundation	Milan	2008 -2018	ITALY	OMA	3	S	Cultural, education	9.6	28.340
Centrale Mazzoni	Venice	2007 - 2010	ITALY	Studio Fon e Architetto Scodellari	3	S	Residential, commercial, offices, spaces for fun, social spaces	1	5.000
Officine del volo	Milan	2003	ITALY	Nicola Gisonda	3	S	Cultural, commercial, offices, social spaces	11.1	1.500
Officine Marconi	Rome	2002 - 2009	ITALY	Avventura Urbana, Isabelle Toussaint and Studio Surra	3	S	Cultural, commercial, sporty, education, spaces for fun, social spaces, spaces for childrens	13.6	22.000
Parco Dora alla Spina 3	Turin	2003 - 2011	ITALY	Latz+Partner GbR, Ing. Vittorio Cappato, Gerd Pfarrè, Ugo Marano, Studio Pession Associato	3	S	Cultural, sporty, spaces for fun, social spaces, spaces for childrens	5.1	450.000
Cantina Santa Margherita	Fossalta di Portogruaro	2016	ITALY	Westway Architects	3	S	Offices	6.2	3.300
Ex Furnace di Riccione	Riccione	2010 - 2014	ITALY	Pietro Carlo Pellegrini Architetto	3	S	Cultural, offices, education	11.7	40.000
Centro produttivo Agostini shoes	Noventa Padovana	2017	ITALY	MIDE architetti	3	NS	Commercial, offices	11.1	800
Ex Acciaierie Ansaldo	Milan	2016	ITALY	Ing. P. Gadda, Ing. Valverti	3	S	Cultural, offices, education	3.3	11.000
Ex stabilimento chimico Mira Lanza	Rome	1998 - 2004	ITALY	Ugo Colombari e Giuseppe De Boni Architetti Associati	3	S	Cultural, residential, social spaces	6	47.100
Environment park - ex Teksid	Turin	1997 - 2005	ITALY	Emilio Ambasz, Benedetto Camerana and Giovanni Durbiano	3	NS	Offices, social spaces	5.5	30.000
Centro culturale Le Ciminiere (Zò)	Catania	1984	ITALY	Nigel Allen	3	S	Cultural, offices, education, social spaces	4	25.000
MACRO	Rome	2001 - 2010	ITALY	Odile Decq and Benoît Cornette	3	S	Cultural, commercial, education, social spaces	2.2	10.000

Padiglione Protiro	Caltagirone	2016 - 2017	ITALY	NOWA Architects	3	NS	Education, spaces for hospitalisation	2.8	400
Xfood - qualcosa di diverso (ExFadda)	San Vito dei Normanni	2014	ITALY	Sandei S.r.l.	3	S	Education, social spaces	24.8	15.000
AMAA Studio	Arzignano	2018	ITALY	AMAA - Collaborative Office For Research And Development	3	NS	Offices	17.5	3.000
Uffici Codebò	Turin	2013	ITALY	Negozio Blu Architetti Associati	3	NS	Offices	8.7	2.000
Ex Carpano - Centro Eataly	Turin	2007	ITALY	Negozio Blu Architetti Associati	3	NS	Cultural, commercial, offices	5.7	11.400
Riuso edificio produttivo: Showroom Buratti	Moncalieri	2009	ITALY	Negozio Blu Architetti Associati	3	NS	Commercial	6.7	1.600
Ex Pastificio Italiano - Albergo AC Hotel	Turin	2005	ITALY	Negozio Blu Architetti Associati	3	S	Cultural, residential	6	6.353
GUCCI Hub	Milan	2016	ITALY	Piuarch	3	S	Cultural, commercial, offices	8.3	30.000
Wooden structure at Launchlabs	Basel	2014	SWITZERLAND	Stereo Architektur	4	NS	Cultural, offices	3.8	4.000
Allez up rock Climbing Gym	Montreal	2013	CANADA	Smith Vigeant Architects	5	NS	Sporty	2.5	1.220
Tower Automotive Building: Museum of Contemporary Art	Toronto	2018	CANADA	architectsAlliance	5	S	Cultural, commercial	5.7	9.700
Salt building	Vancouver	2009	CANADA	Acton Ostry Architects, Goltman Simpson architects	5	NS	Commercial, social spaces	3	1.400
60 Atlantic Avenue	Toronto	2014	CANADA	Quadrangle Architects	5	S	Offices, social spaces	4.2	3.995
Leszczynski Antoniny Manor Intervention	Leszno	2015	POLAND	NA NO WO architekci	6	S	Residential, spaces for hospitalisation	2	8.928
Adaptation of former Granary	Gliwice	2008	POLAND	Medusagroup	6	S	Residential, offices	1.9	5.000
Brothers brewery + Juke Joint BBQ	Auckland	2015	NEW ZEALAND	MA Studio	7	NS	Commercial	2.9	1.100
Mason Bros Warehouse Renovation	Auckland	2016	NEW ZEALAND	Warren and Mahoney	7	NS	Commercial, offices	1.3	5.700
Jellicoe Harbour and Silo Park	Auckland	2011	NEW ZEALAND	Taylor Cullity Lethlean, Wraight + Associates	7	NS	Cultural, spaces for fun, social spaces	2.2	37.000
Morningside warehouses	Auckland	2019	NEW ZEALAND	Fearon Hay Architects	7	NS	Offices	4.9	1.800
Imperial buildings	Auckland	2011	NEW ZEALAND	Fearon Hay Architects	7	S	Commercial	0.6	5.000
North wharf warehouses	Auckland	2011	NEW ZEALAND	Fearon Hay Architects	7	NS	Commercial	1.9	2.600
Fabric warehouse	Auckland	2012	NEW ZEALAND	Fearon Hay Architects	7	NS	Offices, social spaces	3	1.500
Kaomai Museum	Chiang Mai	2018	THAILAND	PAVA architects	8	NS	Cultural	22.6	72
RedFern Warehouse	RedFern	2018	AUSTRALIA	Ian Moore Architects	9	NS	Residential, spaces for hospitalisation	3.3	756
Transformer Fitzroy	Fitzroy	2015	AUSTRALIA	Breathe Architecture	9	NS	Commercial	3.4	237
Paramount House Hotel	Surry Hills	2018	AUSTRALIA	Breathe Architecture	9	NS	Residential	2.6	600
Bays 6-8 Heritage Warehouse office	Sydney	2018	AUSTRALIA	BJB Architects	9	S	Commercial, offices	3.1	2.500
Up-cycled Warehouse	Richmond	2013	AUSTRALIA	Zen Architects	9	NS	Residential	68.3	240
Camperdown warehouse	Sydney	2018	AUSTRALIA	Archer Office	9	S	Residential	4.3	130
Unit B4	Sydney	2012	AUSTRALIA	Make Creative	9	NS	Offices	8.7	800
Flour Mill Summer Hill	Sydney	2016 - 2019	AUSTRALIA	Hassell Studio	9	NS	Residential, commercial, social spaces, spaces for childrens	9.6	25.000
Wertheim Factory Conversion	Melbourne	2014	AUSTRALIA	Kerstin Thompson Architects	9	S	Residential	6.1	30.000
Fitzroy Sheetmetal Factory	Fitzroy	2001	AUSTRALIA	Kerstin Thompson Architects	9	NS	Residential, offices	2.6	500
Rehabilitation of an old factory	Gennevilliers	2017	FRANCE	PARC Architectes	10	NS	Offices	9.5	7.300
Archives Antoni Clavè	Paris	2017	FRANCE	Kengo Kuma & Associates	10	NS	Cultural , offices	4.3	240
Old Mill Rigot refurbishment	Dunkerque	2014	FRANCE	Coldefy & Associés Architectes Urbanistes	10	S	Cultural , commercial, offices	1.4	2.126
La Cartoucherie	Bourg-Les-Valence	2009 - 2016	FRANCE	H2o Architectes	10	S	Cultural, offices, education, social spaces	1.4	2.420
Marseilles Docks	Marseille	2015	FRANCE	5+1AA Alfonso Femia Gianluca Peluffo	10	S	Cultural, commercial, social spaces	2.3	1.951
FRAC Museum	Dunkerque	2013	FRANCE	Lacaton & Vassal	10	NS	Cultural, sporty, social spaces	2.6	11.130
Docks Malraux	Strasbourg	2014	FRANCE	Heintz-Kehr architects	10	S	Residential, commercial, offices	2.7	11.600
Multimedia Library in an Old Factory	Erstein	2011	FRANCE	S&AA	10	S	Cultural	24	1.300
Maison Folie de Wazemmes	Lille	2001 - 2004	FRANCE	NOX and Lars Spuybroek	10	S	Cultural, commercial, spaces for fun, social spaces, spaces for childrens	1.5	5.000
Musée du Sel	Salins-Les-Bains	2009	FRANCE	Michel MALCOTTI, Catherine ROUSSEY, Thierry GHEZA	10	S	Cultural	42.4	1.927
La fosse Delloye / Mining History Centre	Lewarde	1985 - 2002	FRANCE	Nord-Pas de Calais Coalfield Nationalised Mining Company - HBNPC	10	S	Cultural, offices	9.2	4.000
The Docks Dombasles	Le Havre	2005 - 2009	FRANCE	Hamonic + Masson architects	10	NS	Residential, offices	3.2	3.024

Halle Girard Building renovation	Lyon	2019	FRANCE	Vurpas Architectes	10	S	Offices	4.4	4.083
Maison Rouge	Saint Jean du Gard	2011 - 2018	FRANCE	Vurpas Architectes	10	S	Cultural, social spaces	27.5	3.300
SILOS 13	Paris	2014	FRANCE	VIB Architecture	10	NS	Offices	5.6	8.000
Fondation-s	Paris	2018	FRANCE	Lobjoy-Bouvier-Boisseau Architecture	10	NS	Cultural, offices, social spaces	3	1.969
Refunctionalisation of Marconetti ex-mill	Santa Fe	2017	ARGENTINA	Subsecretaría de Obras de Arquitectura Gobierno de la ciudad de Santa Fe	11	S	Education	5.8	4.780
Capitan Central Brewery	Cordoba	2014	ARGENTINA	Guillermo Cacciavillani.Bar Makers	11	S	Commercial	1.7	600
Shanghai shipyard reuse	Shanghai	2018	CHINA	Kengo Kuma & Associates	12	NS	Cultural, commercial	4.3	31.626
Renovation of CRRC 1897 Center	Beijing	2018	CHINA	office PROJECT	12	S	Offices, education	17.7	2.000
Art studio of Xu Hongquan	Beijing	2017	CHINA	office PROJECT	12	NS	Residential, offices	66	1.200
Dave & Bella Headquarters	Hangzhou	2017	CHINA	LYCS Architecture	12	NS	Offices	14.2	7.500
YUE Art Gallery	Shenzhen	2018	CHINA	BLACKhome	12	NS	Cultural, offices	9.3	4.472
Yue Art Gallery	Beijing	2011	CHINA	Tao Lei Architect Studio - Lei Tao, Bozhou Kang, Mingliang Zhao	12	NS	Cultural	16.4	1.600
Hundun University Education Center	Yuzhong Qu	2018	CHINA	VARY DESIGN	12	S	Education	6.2	520
Zhongshan Road coworking space	Chongqing	2018	CHINA	VARY DESIGN	12	NS	Offices	5.2	650
Zhujiadian Brick Kiln Museum	Kunshan	2016	CHINA	Land-Based Rationalism D-R-C	12	S	Cultural	29	1.650
Inlay workshop of UABB	Shenzhen	2017	CHINA	Studio10	12	NS	Offices, education, social spaces	30.9	2.000
Wenzhou MiFang Industry park	Wenzhou	2017	CHINA	FAX ARCHITECTS	12	S	Cultural, commercial, spaces for fun, social spaces	5	35.886
Moling 9 workshop	Nanjing	2017	CHINA	TR Architects	12	NS	Cultural, residential, offices	16.4	40.000
Alila Yangshuo Hotel	Guangxi / Guilin	2017	CHINA	Vector Architects	12	S	Residential, spaces for fun	87.4	16.000
Minsheng Dock Silo renovation	Shanghai	2017	CHINA	Atelier Deshaus	12	S	Cultural, social spaces	8.6	16.322
Silo-top Studio	Guangzhou	2014	CHINA	O-OFFICE architects	12	S	Offices	8.8	621
Youth Hotel of iD Town	Shenzhen	2014	CHINA	O-OFFICE architects	12	NS	Residential, social spaces	49.7	1.800
MJH Gallery of iD Town	Shenzhen	2014	CHINA	O-OFFICE architects	12	NS	Cultural	49.8	2.800
Stone Art Gallery	Guangzhou	2013	CHINA	O-OFFICE architects	12	NS	Cultural	15	1.270
Tianhe Youth Commune	Guangzhou	2017	CHINA	O-OFFICE architects	12	NS	Residential, offices, social spaces	10.8	21.000
Former rubber factory renovation	Kunming	2017	CHINA	Kokaistudios	12	NS	Residential, commercial, offices, sporty, social spaces	26.2	30.000
Chenfeng Group Fashion Hub Factory Renovation	Suzhou	2018	CHINA	Joseph Dejardin	12	NS	Offices	45.8	12.000
77 theatre	Beijing	2016	CHINA	Origin Architects	12	S	Cultural, offices, social spaces	3.5	10.000
UCCA center for contemporary art	Beijing	2017 - 2020	CHINA	OMA	12	S	Cultural	16.4	2.000
Holiday Inn Express Beijing Shougang Silo	Beijing	2015 - 2018	CHINA	China Architecture Design & Research Group	12	NS	Residential	25.3	9.890
Z Gallery	Shenzhen	2014	CHINA	O-OFFICE architects	12	NS	Cultural, social spaces	49.5	2.963
Lianzhou Museum of Photography	Quingyuan	2017	CHINA	O-OFFICE architects	12	NS	Cultural	2.1	3.400
Chongqing Industrial Museum	Chongqing	2019	CHINA	WallaceLiu	12	NS	Cultural	12.2	7.500
SZ-HK Biennale-Silo Reconversion	Shenzhen	2013	CHINA	O-OFFICE architects	12	NS	Cultural	24.9	2.662
Wu Yueshi Art Museum	Beijing	2019	CHINA	Office PROJECT	12	NS	Cultural, commercial	16.7	967
Red Town Art Design Center	Wuhan	2019	CHINA	UAO Design	12	NS	Cultural, commercial	12.9	4.891
Alembic Factory reuse	Vadodara	2018	INDIA	Karan Grover and Associates	13	S	Cultural, education	5.3	1.200
Imagine studio at the trees	Mumbai	2015	INDIA	Studio LOTUS + GPL Design Studio	13	S	Cultural, commercial, social spaces	20	4.047
Group DCA Office	New Delhi	2012	INDIA	DCA Architects	13	NS	Offices	17.5	413
Onomichi U2	Onomichi	2012	JAPAN	Suppose Design Office	14	S	Residential, commercial, social spaces	1.8	2.301
Warehouse of time	Saitama	2017	JAPAN	FT Architects	14	S	Cultural, social spaces	30.9	711
A sake brewery addition	Fukuoka	2015	JAPAN	a-um	14	S	Offices	2.4	450
Lumiere cinema Maastricht	Maastricht	2016	THE NETHERLANDS	JHK Architecten, Verlaan & Bouwstra architecten	15	S	Cultural, commercial	2.7	3.750
The dream factory	Rotterdam	2016	THE NETHERLANDS	Studio Roosegaarde	15	NS	Offices	5	1.000
Masterplan Villa Industria	Hilversum	2007 - 2018	THE NETHERLANDS	Mecanoo	15	S	Residential, social spaces	1.4	74.000

Gouda Cheese Warehouse Loft Apartments	Gouda	2017	THE NETHERLANDS	Mei architects and planners	15	NS	Residential, social spaces	24.8	5.000
NDSM Wharf	Amsterdam	1995 - 2013	THE NETHERLANDS	Stiching Kinetisch Noord	15	S	Cultural, offices, education, social spaces	7	7.300
Kraanspoor	Amsterdam	2007	THE NETHERLANDS	OTH Architecten	15	NS	Offices	7.1	12.500
Unilever Nederland BV	Rotterdam	2001 - 2008	THE NETHERLANDS	JHK Architecten	15	S	Offices	4.6	14.000
Mout foodhall	Hilversum	2016 - 2017	THE NETHERLANDS	Zecc Architecten	15	S	Cultural, commercial	0.6	750
Werkspoor factory	Utrecht	2012 - 2019	THE NETHERLANDS	Zecc Architecten	15	NS	Offices	3.4	9.200
Polygonal Workshop	Tilburg	2015 - 2017	THE NETHERLANDS	Zecc Architecten	15	NS	Cultural, commercial	1.6	1.500
Water Tower	Utrecht	2012 - 2019	THE NETHERLANDS	Zecc Architecten	15	S	Residential, offices	2.2	1.800
Watertower dwelling	Soest	2002 - 2004	THE NETHERLANDS	Zecc Architecten	15	S	Residential	24	280
Water tower	Sint Jansklooster	2007 - 2014	THE NETHERLANDS	Zecc Architecten	15	S	Social spaces	28.9	500
Transformation train Depot	Utrecht	2015 - 2017	THE NETHERLANDS	Zecc Architecten	15	S	Offices	2.2	1.200
House M&M Funen	Amsterdam	2017 - 2018	THE NETHERLANDS	Claudia Linders, NEXT architects	15	NS	Residential	4	269
Innovation powerhouse	Eindhoven	2018	THE NETHERLANDS	Atelier van Berlo, Eugelink Architectuur and De Bever Architecten	15	S	Offices	3.1	11.000
Herbestemming Lakfabriek KVL Oisterwijk	Oisterwijk	2018	THE NETHERLANDS	Wenink Holtkamp Architecten	15	S	Residential, offices	10.7	1.200
Heberstemming Zwarte Silo Deventer	Deventer	2015	THE NETHERLANDS	Wenink Holtkamp Architecten	15	S	Commercial, offices	1.6	1.000
Borneo Sporenburg Docks	Amsterdam	1996 - 2000	THE NETHERLANDS	Adriaan Geuze, Sebastiaan Riquois, Wim Kloosterboer, Yushi Uehara, West8, KAAN architecten	15	NS	Residential, offices	4.4	250.000
LocHal Library	Tilburg	2016 - 2018	THE NETHERLANDS	CIVIC - TheCloudCollective and Mecanoo	15	NS	Cultural, commercial, offices, education, social spaces	2.1	11.200
Mindlabs	Tilburg	2017	THE NETHERLANDS	CIVIC - TheCloudCollective	15	NS	Offices, education	1.7	8.200
Gearwheel Factory Reconversion	Amsterdam	2015	THE NETHERLANDS	Ronald Janssen Architects, Donald Osborne Architect	15	NS	Residential	1.8	800
Silodam	Amsterdam	2003	THE NETHERLANDS	MVRDV	15	NS	Residential, commercial, offices, social spaces	4.3	19.500
Aripaev office	Tallinn	2017	ESTONIA	Arhitekt 11	16	S	Cultural, commercial, offices	3.8	2.739
Fahle House	Tallinn	2016	ESTONIA	KOKO Architects	16	S	Residential, commercial, offices, spaces for fun, social spaces	5.1	19.400
Rotermann Carpenter's Workshop	Tallinn	2009	ESTONIA	KOKO Architects	16	S	Residential, commercial, offices,	2.5	2.700
Tallinn Creative Hub	Tallinn	2015	ESTONIA	Kavakava	16	S	Cultural, social spaces	1.9	11.200
Rotermann Grain Elevator	Tallinn	2016	ESTONIA	KOKO Architects	16	S	Cultural, offices, education	2.3	5.600
Rotermann's Old and New Flour Storage	Tallinn	2009	ESTONIA	HGA (Hayashi – Gross Schmidt Arhitektuur)	16	S	Commercial, offices	2.4	9.002
Baltik station market	Tallinn	2017	ESTONIA	KOKO Architects	16	NS	Commercial	1.9	25.000
Seaplane Harbour	Tallinn	2012	ESTONIA	KOKO Architects	16	S	Cultural	2.9	8.000
Boiler house	Libcice nad Vltavou	2018	CZECH REPUBLIC	Atelier Hoffman	17	S	Cultural, social spaces	23.1	886
Coal Mill	Libcice nad Vltavou	2012	CZECH REPUBLIC	Atelier Hoffman	17	S	Offices	23.4	150
Economia building	Prague	2013	CZECH REPUBLIC	Ricardo Bofill	17	S	Offices	1.9	7.000
The Kamenice brewery	Kamenice Nad Lipou	2018	CZECH REPUBLIC	OTA Atelier	17	S	Commercial	21.2	2.290
BilkaBarn	Bilka	2012	CZECH REPUBLIC	A2F Architects	17	S	Residential	13.7	168
Gunpowder Mill	Waltham Abbey	2009	GREAT BRITAIN	Pollard Thomas Edwards Architects	18	S	Offices	28.5	4.000
The Granary	Barking	2011	GREAT BRITAIN	Pollard Thomas Edwards Architects	18	S	Offices	17.5	2.748
Diespeker Wharf	City Road Basin	1996	GREAT BRITAIN	Pollard Thomas Edwards Architects	18	S	Cultural, residential, offices	4.7	1.858
Shoreham Street	Sheffield	2012	GREAT BRITAIN	Project Orange	18	S	Commercial, offices	1.6	800
RCA Sackler building	London	2009	GREAT BRITAIN	Haworth Tompkins Limited	18	NS	Cultural, education	6	1.280
Battersea power station	London	2016 - 2025	GREAT BRITAIN	Rafael Vinoly, WilkinsonEyre, Purcell Architects, BIG, Norman Foster and Frank Gehry	18	S	Cultural, residential, commercial, offices, sporty, education, spaces for fun, social spaces, spaces for childrens	4.5	1.214.057
Tate Gallery	London	1995 - 2000	GREAT BRITAIN	Herzog & de Meuron	18	S	Cultural, commercial, offices	3.2	34.560

KAMPUS	Manchester	2016 - 2020	GREAT BRITAIN	Mecanoo	18	S	Residential, commercial, offices, social spaces	2	44.000
Bombay Sapphire Distillery	Hampshire	2010 - 2014	GREAT BRITAIN	Heatherwick Studio	18	S	Cultural, commercial, offices	43.9	4.500
The Egg Shed Heritage & Community Centre	Ardrishaig	2019	GREAT BRITAIN	Oliver Chapman Architects	18	NS	Cultural, offices, social spaces	4	270
Northampton International Academy	Northampton	2019	GREAT BRITAIN	Architecture Initiative	18	NS	Cultural, offices, education, social spaces	1.8	22.250
New theatre in Santa Maria Port	El Puerto	2007	SPAIN	Daroca Arquitectos	19	S	Cultural	1.7	5.446
Reforma y Rehabilitacion de la Nave industrial Can Minguell	Barcelona	2010	SPAIN	Toni Girones	19	S	Cultural, offices, social spaces, spaces for childrens	2.3	2.100
The Factory	Terrassa	2011	SPAIN	Pepe Gascón	19	S	Offices	37.2	593
Hotel and restaurant in the Montalvan Pottery Factory	Sevilla	2018	SPAIN	AF6 Arquitectos	19	S	Residential, commercial	3.9	1.937
Matadero	Madrid	2000 - 2012	SPAIN	Arturo Franco, Fabrice Van Teslaar, Diego Castellanos, Espacio sin intervenir	19	S	Cultural, commercial, offices, education, social spaces, spaces for childrens	3.5	165.415
Caixa Forum	Madrid	2001 - 2008	SPAIN	Herzog & de Meuron	19	S	Cultural, commercial, offices, social spaces	1.6	1.934
Medialab-Prado	Madrid	2008	SPAIN	Langarita Navarro Arquitectos	19	S	Cultural, commercial, offices, education	1.5	3.500
La NAVE (Fabrica Boetticher)	Madrid	2006 - 2009	SPAIN	Josè Maria Churtichaga and Joaquin Lizasoain	19	S	Cultural, offices, education	11.6	12.317
The factory	Sant Just Desvern	1973 - 2018	SPAIN	Ricardo Bofill	19	S	Cultural, residential, offices, spaces for fun, social spaces	17.6	31.000
Can Ribas	Palma di Maiorca	2010 - 2011	SPAIN	Jaime J. Ferrer Forés	19	S	Cultural, social spaces	6.1	287
CAN FRAMIS Museum	Barcelona	2008	SPAIN	BAAS architecture studio	19	S	Cultural, social spaces	6.6	5.800
Oliva Artés Factory renovation	Barcelona	2015	SPAIN	BAAS architecture studio	19	NS	Cultural	6.7	1.456
Dàoiz y Velarde Cultural Center	Venturada	2013	SPAIN	Rafael de La-hoz	19	S	Cultural	3.3	6.850
El Teatro	Barcelona	2019	SPAIN	Cadaval & Solà-Morales	19	NS	Residential, offices	7	250
Malmo Saluhall	Malmo	2016	SWEDEN	Wingårdh Arkitektkontor AB	20	S	Commercial	1.1	1.500
Octapharma Brewery	Stockolm	2011 - 2015	SWEDEN	Joliark	20	S	Commercial, offices, education	4.1	7.400
Warehouse "Maganiset"	Malmo	2013	SWEDEN	Metro Arkitekter	20	NS	Offices	2.2	7.500
Malha	Sao Cristovao	2016	BRASIL	Tavares Duayer Arquitetura	21	NS	Offices	7.9	2.950
SESC Pompeia	Sao Paulo	1977	BRASIL	Lina Bo Bardi	21	S	Cultural, sporty, social spaces, spaces for children	6.8	23.571
The International School of Hout Bay	Cape Town	2013	SOUTH AFRICA	Luis Mira Architects, StudioMAS, Sergio Aguilar	22	NS	Education, sporty	18.2	1.610
Zeitz Museum of Contemporary Art Africa	Cape Town	2017	SOUTH AFRICA	Heatherwick Studio	22	S	Cultural	2.6	9.500
Mill Junction	Johannesburg	2014	SOUTH AFRICA	Citiq students	22	NS	Cultural, residential, commercial, sporty, education, social spaces, spaces for childrens	2.6	13.200
Kanaal in Wijnegem	Wijnegem	2015	BELGIUM	Stéphane Beel Architects	23	S	Cultural, residential, offices	12.9	13.090
MAC Museum of Contemporary Art of Grand Hornu	Boussu	2002	BELGIUM	Atelier d'architecture Pierre Hebbelinck	23	S	Cultural, social spaces	12.9	7.000
Buurtsporthal Parkloods	Antwerp	2007 - 2011	BELGIUM	Verdickt & Verdickt Architecten	23	S	Cultural, offices, sporty	2.8	12.785
HoofdKantoor Wit-Gele Kruis	Ghent	2009 - 2013	BELGIUM	Archipl Architecten	23	S	Offices, social spaces	4.4	3.126
Texture Kortrijk	Kortrijk	2011 - 2014	BELGIUM	NoAarchitecten	23	S	Residential, offices, education	6.2	15.000
Savonnerie Heymans	Brussels	2005 - 2012	BELGIUM	MDW Architecture	23	S	Residential, social spaces	2.5	6.500
Residential Complex Le Lorrain	Molenbeek-St-Jean	2006 - 2011	BELGIUM	MDW Architecture	23	NS	Residential, social spaces	2.1	1.484
Cultural center Lamot	Mechelen	2005	BELGIUM	51n4e architecten and Architekten kooperatief	23	S	Cultural, commercial	2.5	1.300
C-mine	Ghent	2005 -2010	BELGIUM	51n4e architecten	23	S	Cultural, commercial, offices, education, social spaces	2.9	75.000

The Tervahovi Silos	Oulu	2014	FINLAND	PAVE Architects	24	S	Residential	5.7	7.700
Bolshevik factory Museum of Russian Impressionism	Moscow	2014	RUSSIA	John McAslan + Partners	25	S	Cultural, offices, social spaces	6.5	55.000
Archi Loft	Moscow	2019	RUSSIA	Geometrix Design	25	NS	Cultural, spaces for fun, social spaces	17.3	450
GES2	Moscow	2015 - 2020	RUSSIA	Renzo Piano Building Workshop	25	S	Cultural, commercial, social spaces	2.3	22.500
Zollverein Coal Mine Industrial Complex Zukunfts Zentrum Zollverein	Essen	1989 - 2007	GERMANY	OMA, Heinrich Böll, Norman Foster and SANAA	26	S	Cultural, commercial, sporty, spaces for fun, social spaces, spaces for childrens	5.5	1.000.000
Landshaftspark	Duisburg	1991 - 1999	GERMANY	Latz + Partner	26	S	Cultural, sporty, spaces for fun, social spaces, spaces for childrens	7.5	2.000.000
The new warehouse Depot	Leverkusen	2012	GERMANY	Heinrich Böll Architekt	26	S	Cultural, residential, offices	5.4	1.080
Pump House	Bochum	2012	GERMANY	Heinrich Böll Architekt	26	S	Commercial, social spaces	2.6	1.000
Energeticon Alsdorf	Alsdorf	2014	GERMANY	Heinrich Böll Architekt + Atelier Brückner	26	S	Cultural, residential, commercial, social spaces, spaces for childrens	15.3	3.000
Steam Blower House	Bochum	2010	GERMANY	Heinrich Böll Architekt	26	S	Cultural	2.6	2.500
Hall 32	Gummersbach	2013	GERMANY	Heinrich Böll Architekt	26	S	Cultural, commercial	1.4	1.440
Elbphilarmonie	Hamburg	2008 - 2017	GERMANY	Herzog & de Meuron	26	S	Cultural, residential, commercial, offices, spaces for fun, social spaces	2.3	120.000
Kulturbunker	Frankfurt	2004	GERMANY	Index Architekten	26	S	Cultural, residential, offices, education	5.4	600
Museum Kuppersmuhle	Duisburg	2000 - 2015	GERMANY	Herzog & de Meuron	26	S	Cultural	1.5	3.600
Kulturspeicher	Wurzburg	2002	GERMANY	Bruckner & Bruckner Architekten	26	S	Cultural	2.5	3.500
DAS Silo	Hamburg	2000 - 2005	GERMANY	bhl-Architekten	26	S	Residential, commercial, offices	14.8	15.750
U-Boat Hall	Hannover	2012	GERMANY	Bolles + Wilson	26	NS	Commercial	3.6	7.300
KPTN Warehouse Reconversion	Hamburg	2019	GERMANY	blauraum Architekten	26	S	Cultural, residential, commercial	3	48.700
Library Kressbronn a. B.	Kressbronn	2018	GERMANY	Steimle Architekten	26	NS	Cultural, commercial	10.1	860
The warehouse hotel	Singapore	2016	SINGAPORE	Zarch Collaboratives	27	S	Residential	3	2.102
Gasometers	Wien	1995 - 2001	AUSTRIA	Jean Nouvel, Coop Himmelblau, Manfred Wehdorn and Wilhelm Holzbauer	28	S	Cultural, residential, commercial, offices, sporty, education, spaces for fun, social spaces, spaces for childrens	7.3	55.000
Drangar Renovation	Snæfellsnes peninsula	2019	ICELAND	Studio Granda	29	NS	Residential	37.4	1.056
Grünerløkka Studenthus	Oslo	2001	NORWAY	HRTB Arkitekter AS	30	NS	Residential	2.6	9.450
The iron Foundry	Bergen	2006 - 2014	NORWAY	LINK Arkitektur	30	NS	Residential, commercial, offices, social spaces	3.2	32.000
Reconversion of the Robinson factory and space	Portalegre	2011	PORTUGAL	Edoardo Souto de Moura and Graça Correia	31	S	Cultural, commercial, social spaces	1.6	60.000
Jazz Loft	Budapest	2005 - 2018	HUNGARY	Bence and Gabor Turanyi (T2.a)	32	S	Residential, social spaces	6.4	4.500
Luxembourg Science Center	Luxembourg	2019 - 2022	LUXEMBOURG	SKOLNICK Architecture + Design Partnership	33	S	Cultural, education, social spaces, spaces for childrens	25.6	27.871
ARC University of Nicosia	Nicosia	2013	CYPRUS	YIORGOS HADJICHRISTOU ARCHITECTS	34	NS	Offices, education, social spaces	4.4	10.000
CDLE Offices	Mexico City	2015	MEXICO	R-Zero	35	NS	Cultural, offices	2	1.000
Layered House	Buyeo-gun	2017	SOUTH KOREA	STARSIS	36	NS	Residential	15	76
Growing Space	Jung-gu	2018	SOUTH KOREA	STARSIS	36	NS	Offices	4	432







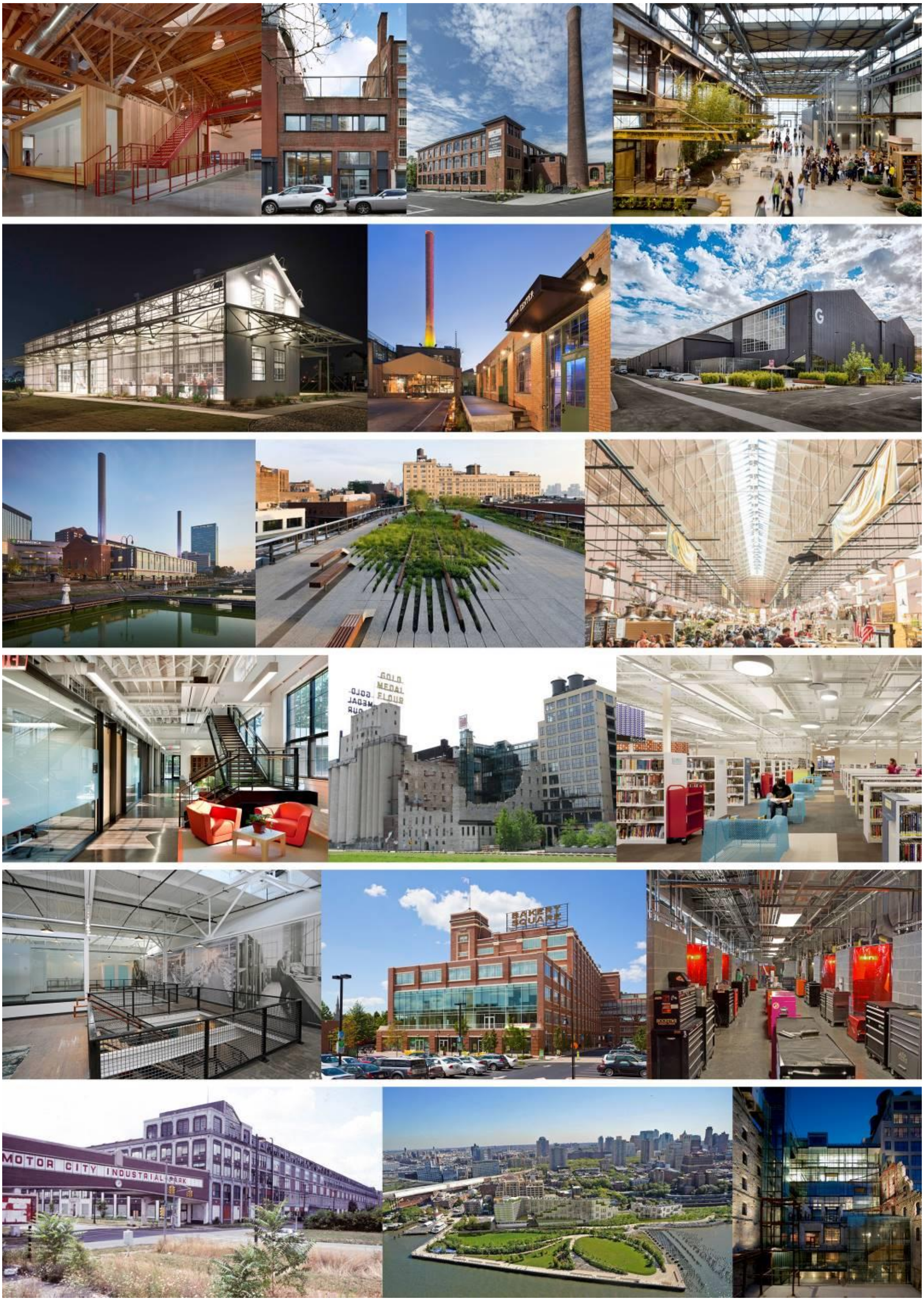


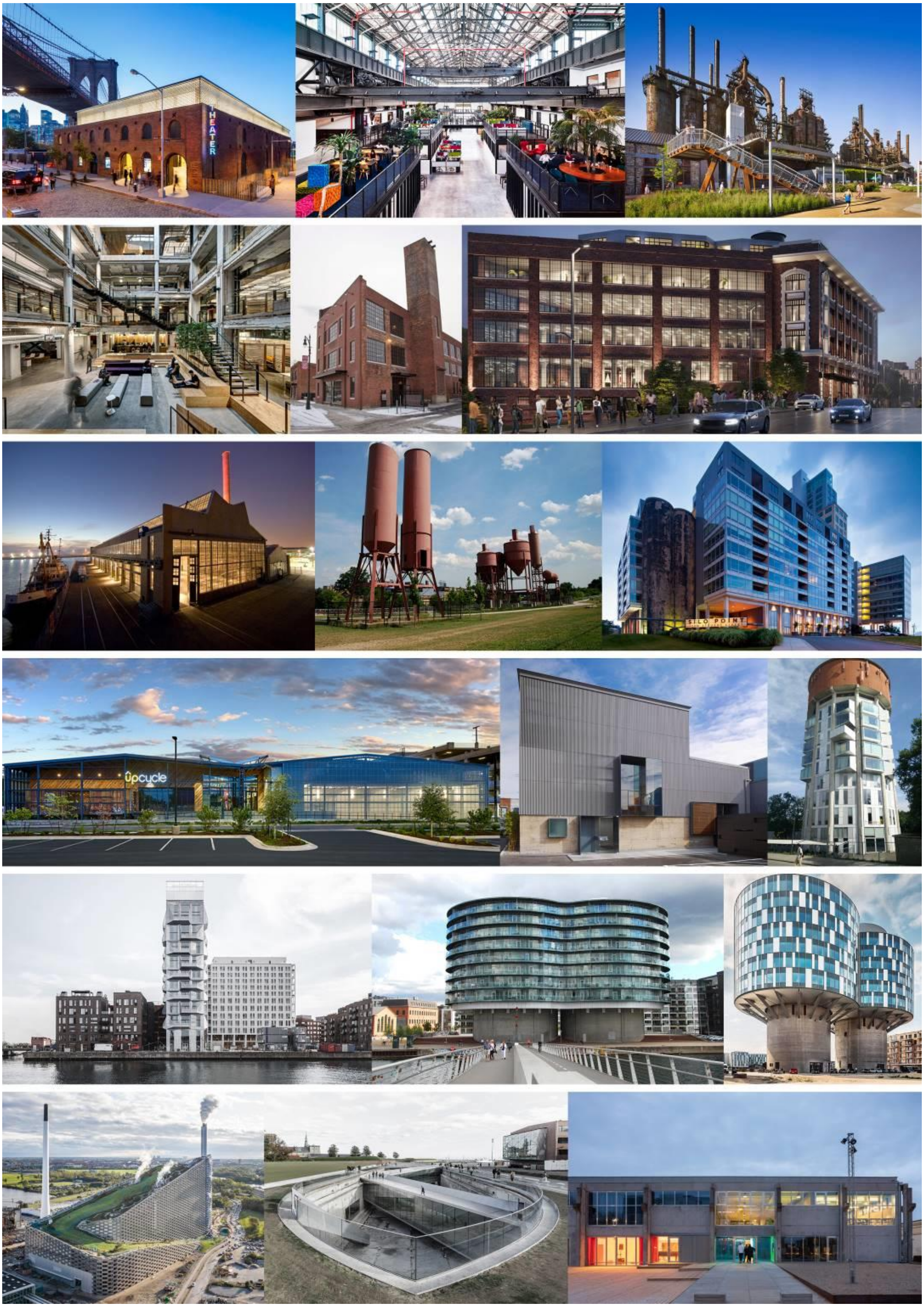




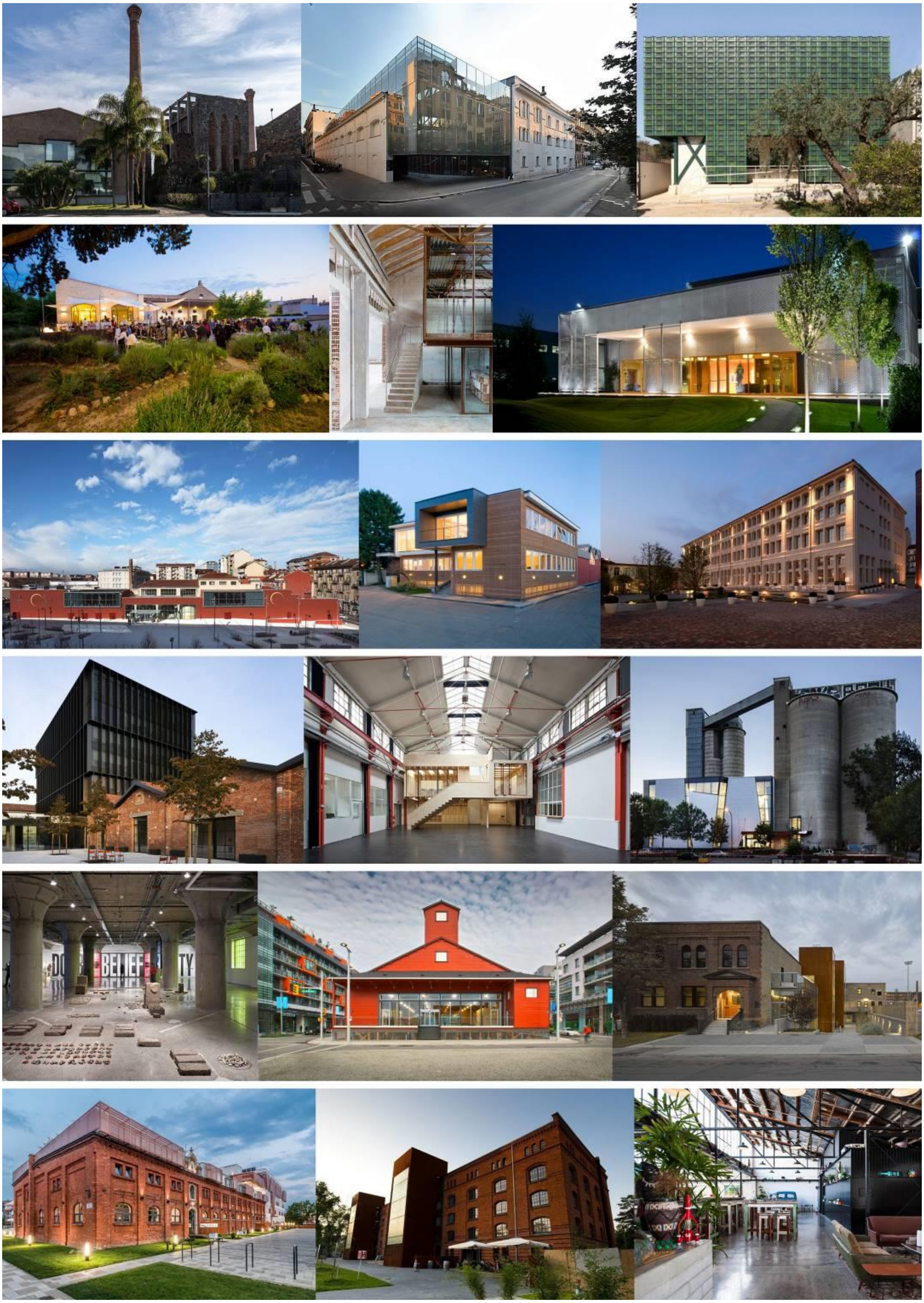


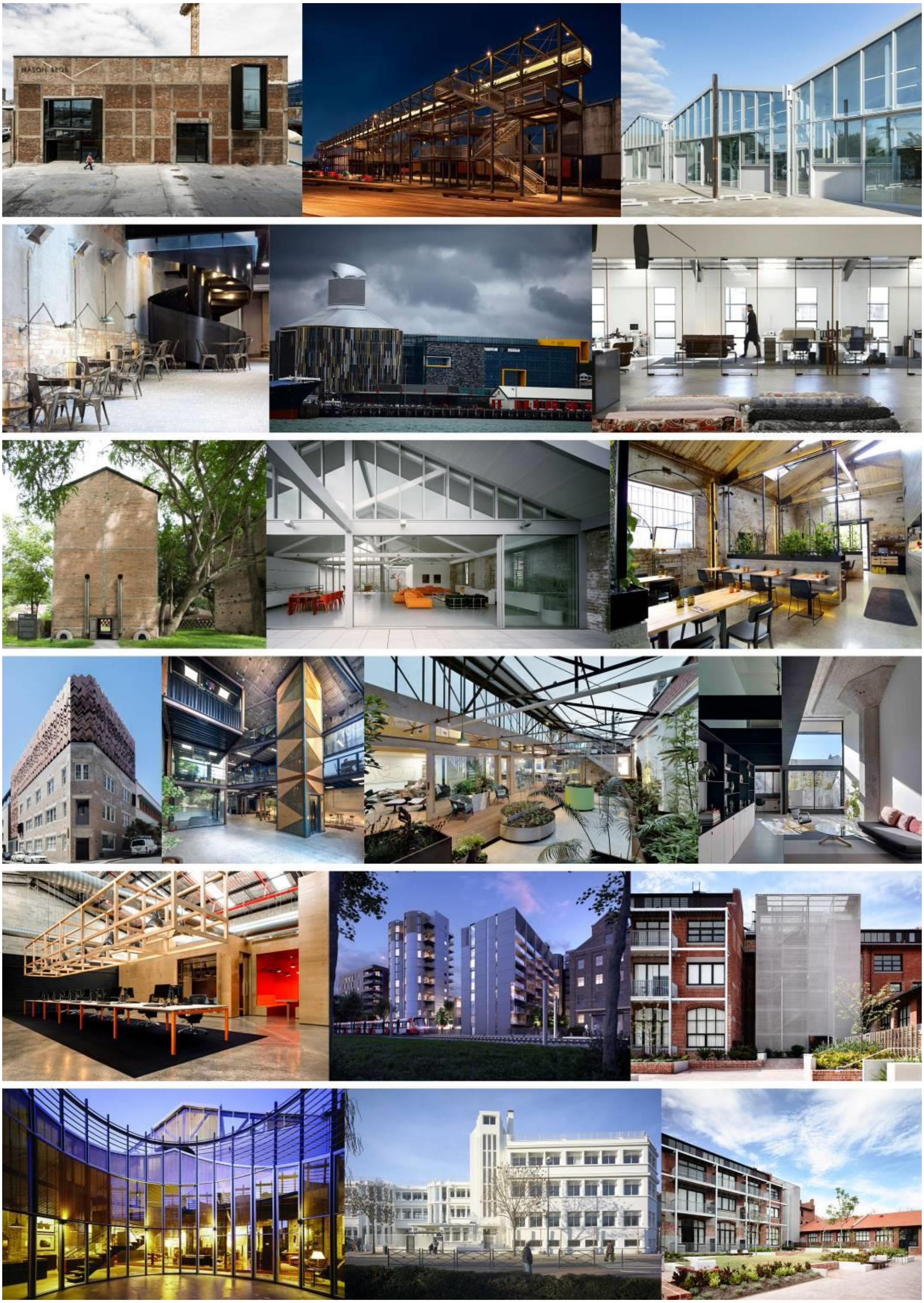




GOLD MEDAL FLOUR
BAKERY SQUARE
MOTOR CITY INDUSTRIAL PARK



upcycle
SILO POINT




MASON BROS





LES DOCK



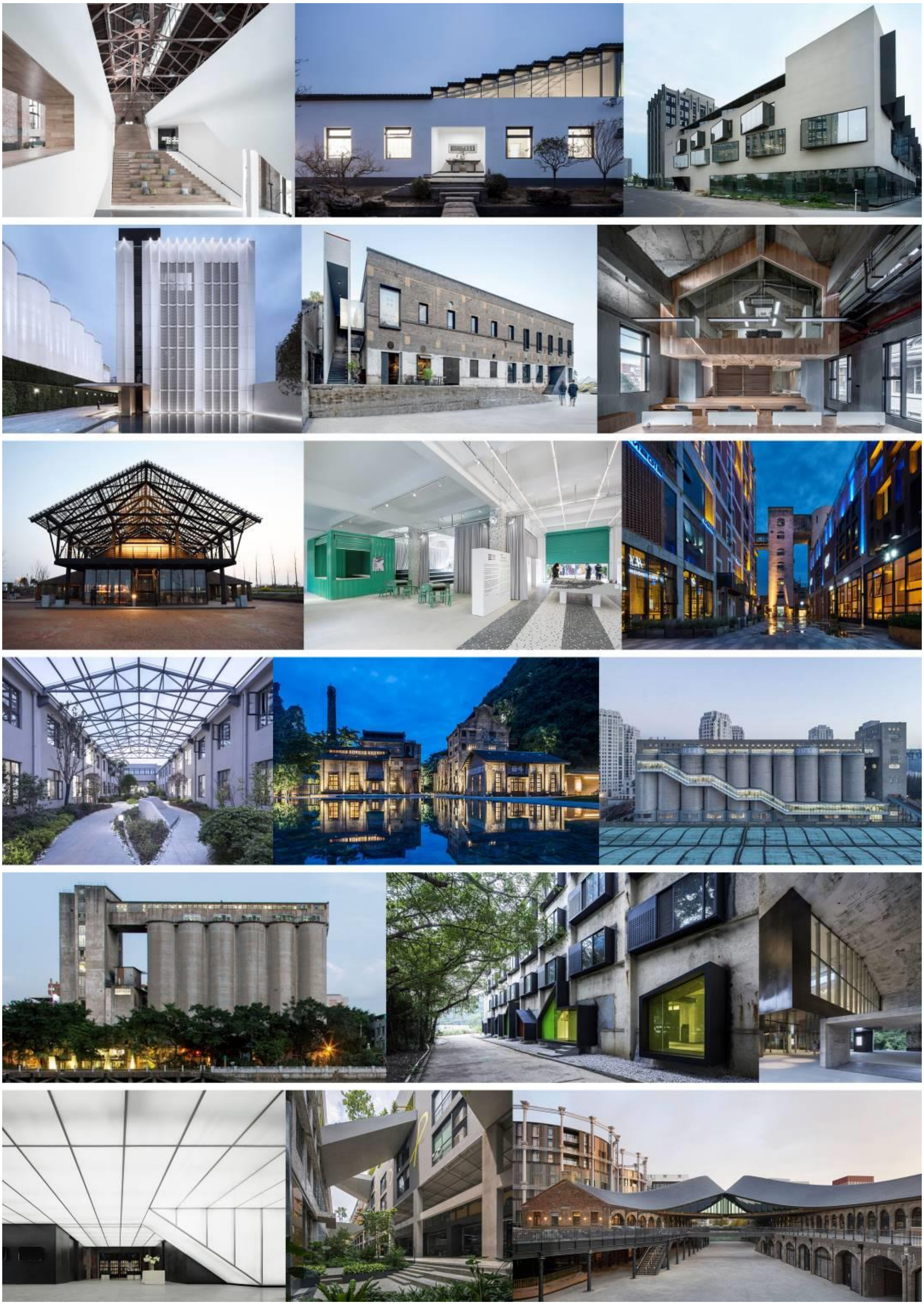














77 THEATRE

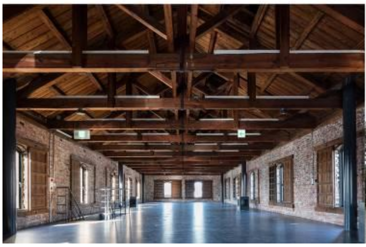


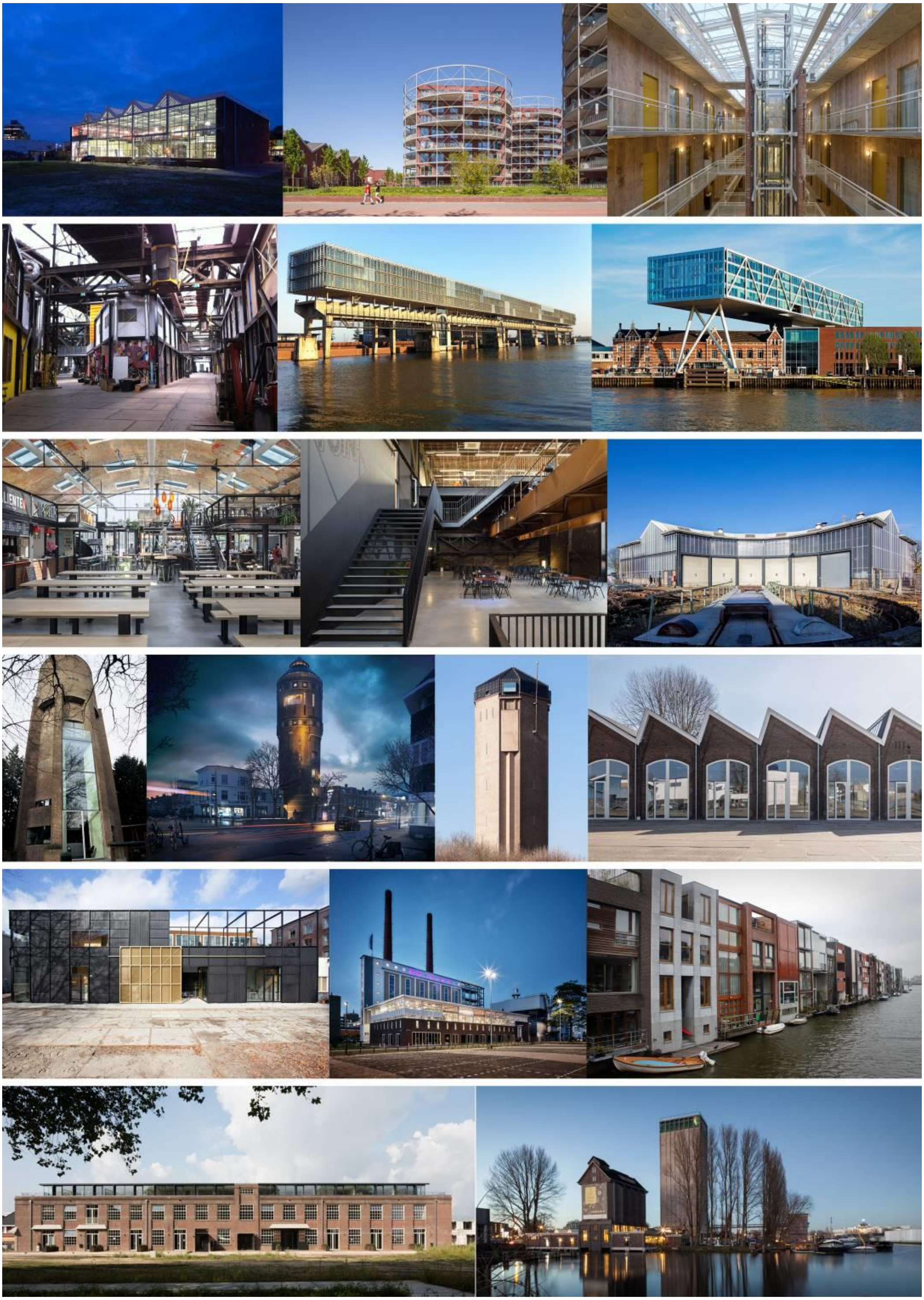


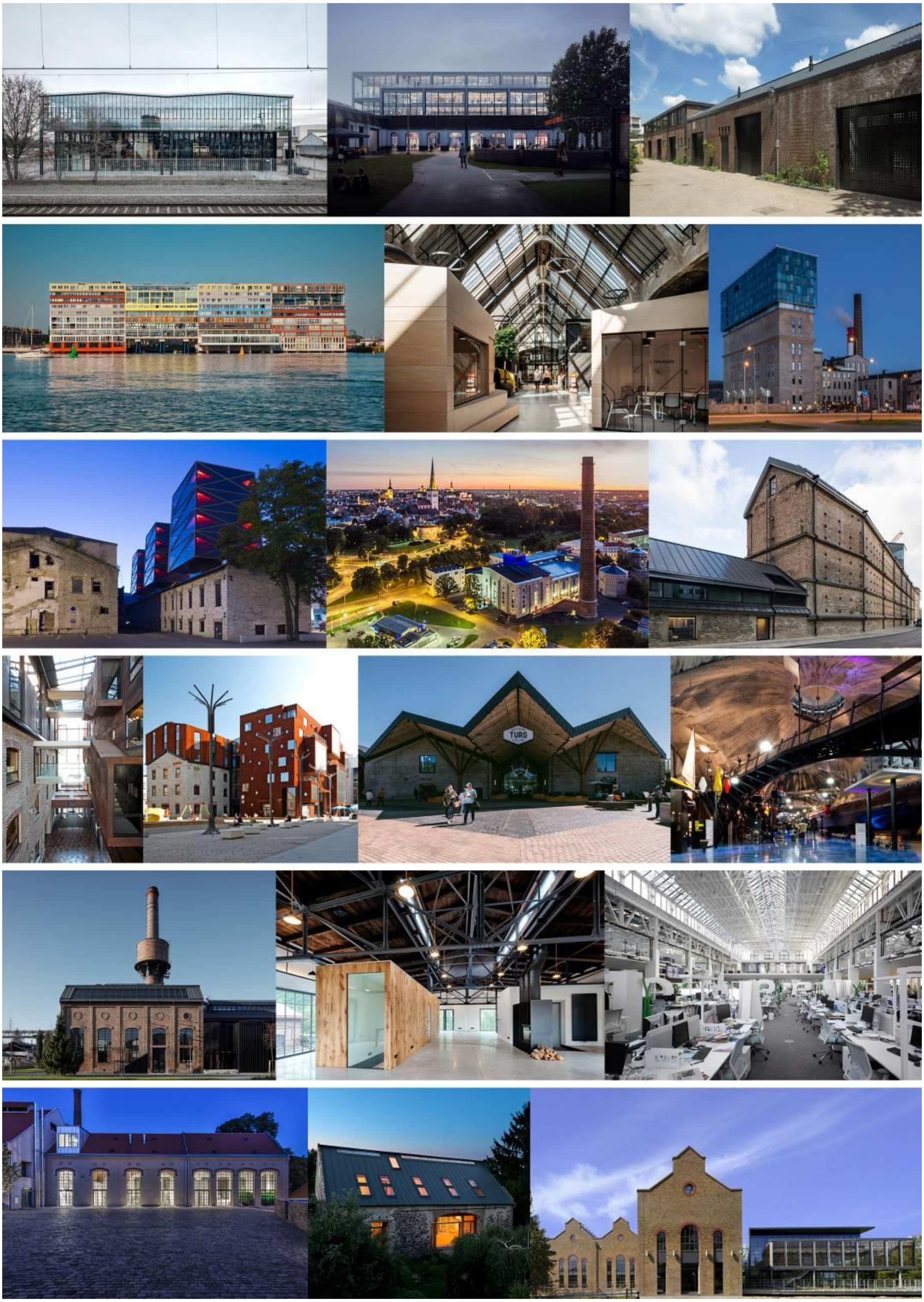






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Painting













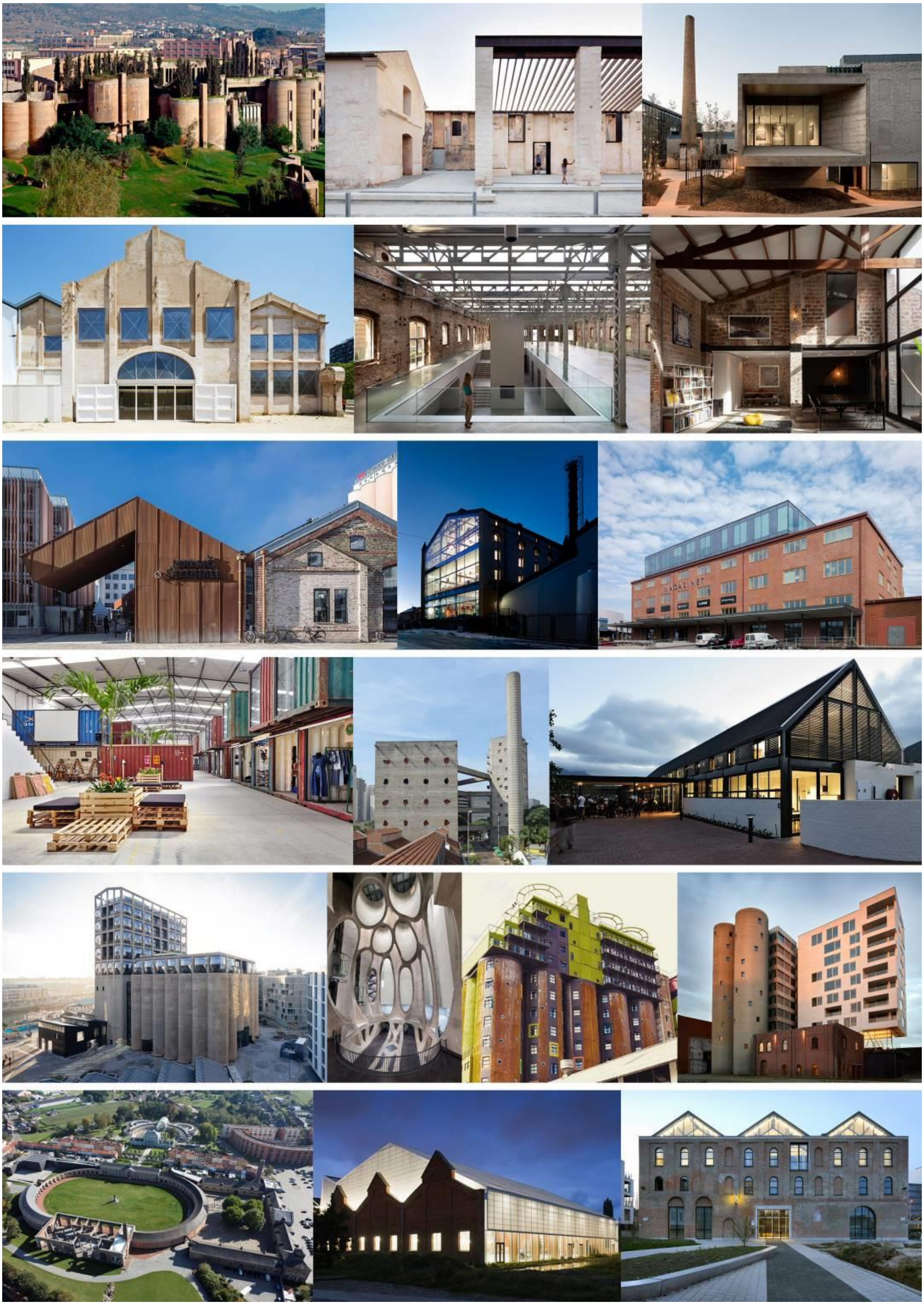





BROUWERIJ LAMOT













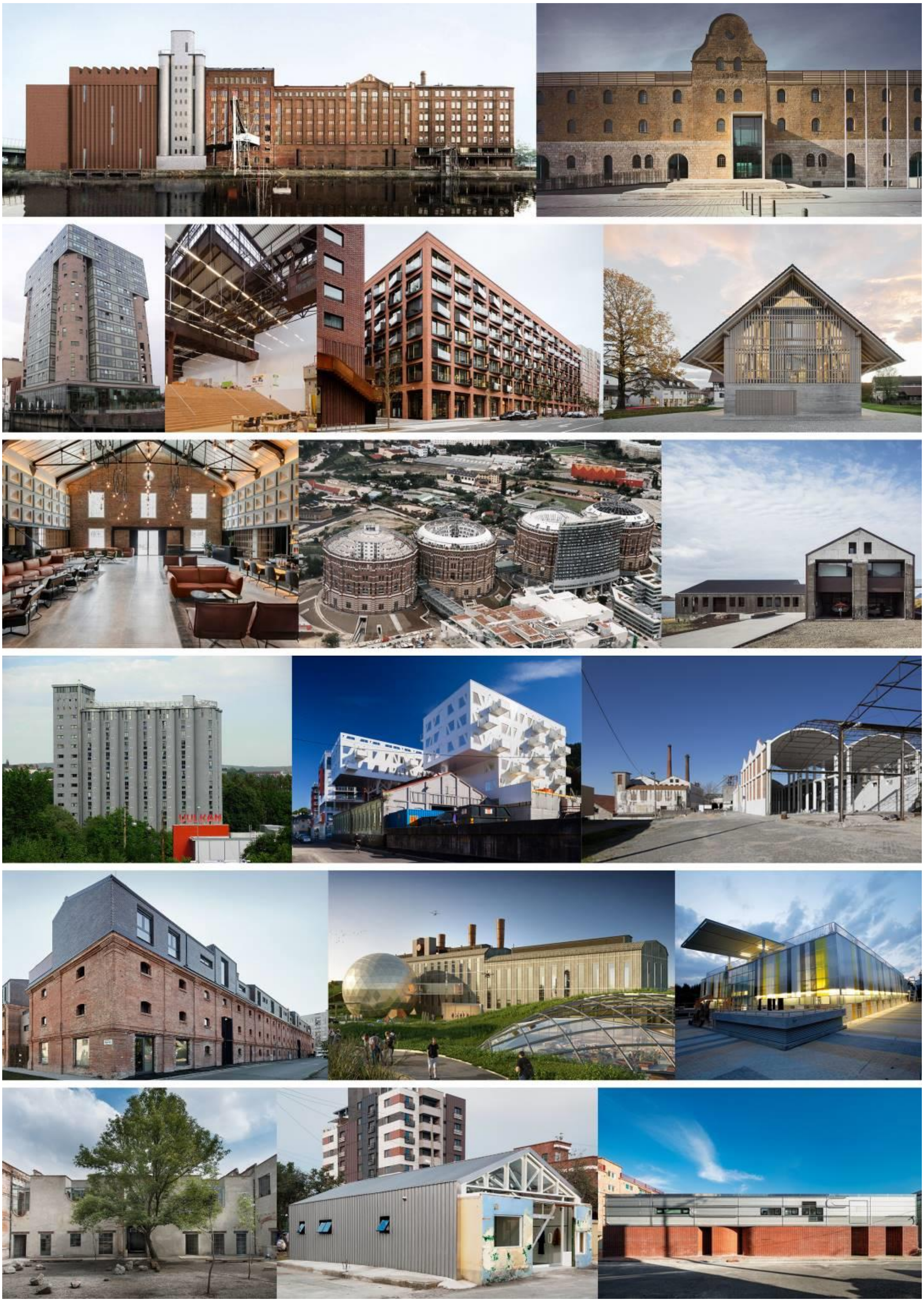

ANNEX B

(DCS main categories, attributes, sub-attributes 1, sub-attributes 2 and activities list and parameters weights)

Category	Code	Weight (%)	Attribute	Code	Weight (%)	Sub-attributes 1	Code	Weight (%)	Sub-attributes 2	Code	Weight (%)	Activities	Code	Weight (%)
						Envelope A1.1	A1.1	0.21	High	A1.1.1	0.21			
									Medium	A1.1.2	0.14			
									Low	A1.1.3	0.07			
						Existent materials conditions A1.2	A1.2	0.22	High	A1.2.1	0.22			
									Medium	A1.2.2	0.15			
									Low	A1.2.3	0.07			
						Structural decay A1.3	A1.3	0.27	Pillars A1.3.1	A1.3.1	0.03	High	A1.3.1.1	0.03
												Medium	A1.3.1.2	0.02
												Low	A1.3.1.3	0.01
									Beams A1.3.2	A1.3.2	0.026	High	A1.3.2.1	0.026
												Medium	A1.3.2.2	0.017
												Low	A1.3.2.3	0.009
									Floors A1.3.3	A1.3.3	0.032	High	A1.3.3.1	0.032
												Medium	A1.3.3.2	0.021
												Low	A1.3.3.3	0.011
									Roof A1.3.4	A1.3.4	0.074	High	A1.3.4.1	0.074
												Medium	A1.3.4.2	0.049
												Low	A1.3.4.3	0.025
									Junctions A1.3.5	A1.3.5	0.04	High	A1.3.5.1	0.04
												Medium	A1.3.5.2	0.027
												Low	A1.3.5.3	0.013
									Foundation A1.3.6	A1.3.6	0.014	High	A1.3.6.1	0.014
												Medium	A1.3.6.2	0.009
												Low	A1.3.6.3	0.005
									Walls A1.3.7	A1.3.7	0.048	High	A1.3.7.1	0.048
												Medium	A1.3.7.2	0.032
												Low	A1.3.7.3	0.016
									Vertical connectors A1.3.8	A1.3.8	0.006	High	A1.3.8.1	0.006
												Medium	A1.3.8.2	0.004
												Low	A1.3.8.3	0.002
						Plants obsolescence A1.4	A1.4	0.2	Cooling system A1.4.1	A1.4.1	0.028	High	A1.4.1.1	0.028
												Medium	A1.4.1.2	0.019
												Low	A1.4.1.3	0.009
									Ventilation system A1.4.2	A1.4.2	0.019	High	A1.4.2.1	0.019
												Medium	A1.4.2.2	0.013
												Low	A1.4.2.3	0.006
									Gas plant A1.4.3	A1.4.3	0.013	High	A1.4.3.1	0.013
												Medium	A1.4.3.2	0.009
												Low	A1.4.3.3	0.004
									Water system A1.4.4	A1.4.4	0.025	High	A1.4.4.1	0.025
												Medium	A1.4.4.2	0.017
												Low	A1.4.4.3	0.008
									Heating system A1.4.5	A1.4.5	0.023	High	A1.4.5.1	0.023
												Medium	A1.4.5.2	0.015
												Low	A1.4.5.3	0.008
									Electric system A1.4.6	A1.4.6	0.026	High	A1.4.6.1	0.026
												Medium	A1.4.6.2	0.017
												Low	A1.4.6.3	0.009
									Exhaust system A1.4.7	A1.4.7	0.023	High	A1.4.7.1	0.023
												Medium	A1.4.7.2	0.015
												Low	A1.4.7.3	0.008
									Water collection plant A1.4.8	A1.4.8	0.024	High	A1.4.8.1	0.024
												Medium	A1.4.8.2	0.016
												Low	A1.4.8.3	0.008
									Photovoltaic system A1.4.9	A1.4.9	0.013	High	A1.4.9.1	0.013
												Medium	A1.4.9.2	0.009
												Low	A1.4.9.3	0.004
									Fire-fighting system A1.4.10	A1.4.10	0.007	High	A1.4.10.1	0.007
												Medium	A1.4.10.2	0.005
												Low	A1.4.10.3	0.002

Building decay A1	A1	2.2	Image obsolescence A1.5	A1.5	0.16	Alveolization A1.5.1	A1.5.1	0.007			
						Color alteration A1.5.2	A1.5.2	0.021			
						Deformation A1.5.3	A1.5.3	0.004			
						Surface deposit A1.5.4	A1.5.4	0.024			
						Detachment A1.5.5	A1.5.5	0.020			
						Efflorescence A1.5.6	A1.5.6	0.016			
						Cracking A1.5.7	A1.5.7	0.021			
						Missing parts A1.5.8	A1.5.8	0.009			
						Bulge A1.5.9	A1.5.9	0.013			
						Oxidation A1.5.10	A1.5.10	0.010			
						Cover expulsion A1.5.11	A1.5.11	0.016			
			Technological obsolescence A1.6	A1.6	0.18	Shadings obsolescence A1.6.1	A1.6.1	0.045	High	A1.6.1.1	0.045
									Medium	A1.6.1.2	0.03
									Low	A1.6.1.3	0.015
						Vertical closures obsolescence A1.6.2	A1.6.2	0.056	High	A1.6.2.1	0.056
									Medium	A1.6.2.2	0.037
									Low	A1.6.2.3	0.019
						Alarm system obsolescence A1.6.3	A1.6.3	0.025	High	A1.6.3.1	0.025
									Medium	A1.6.3.2	0.017
									Low	A1.6.3.3	0.008
						Technologies obsolescence A1.6.4	A1.6.4	0.054	High	A1.6.4.1	0.054
									Medium	A1.6.4.2	0.036
									Low	A1.6.4.3	0.018
			Functional decay A1.7	A1.7	0.19	Spatial decay A1.7.1	A1.7.1	0.018	High	A1.7.1.1	0.018
									Medium	A1.7.1.2	0.012
									Low	A1.7.1.3	0.006
						Spatial flow difficulties A1.7.2	A1.7.2	0.049	High	A1.7.2.1	0.049
									Medium	A1.7.2.2	0.033
									Low	A1.7.2.3	0.016
						Inflexibility to host new functions A1.7.3	A1.7.3	0.018	High	A1.7.3.1	0.018
									Medium	A1.7.3.2	0.012
									Low	A1.7.3.3	0.006
						Lack of vertical connectors A1.7.4	A1.7.4	0.037	High	A1.7.4.1	0.037
									Medium	A1.7.4.2	0.025
									Low	A1.7.4.3	0.012
						Lack of escape routes A1.7.5	A1.7.5	0.049	High	A1.7.5.1	0.049
									Medium	A1.7.5.2	0.033
									Low	A1.7.5.3	0.016
						Lack of parking areas A1.7.6	A1.7.6	0.019	High	A1.7.6.1	0.019
									Medium	A1.7.6.2	0.013
									Low	A1.7.6.3	0.006
			Dampness A1.8	A1.8	0.2	Rising damp A1.8.1	A1.8.1	0.064	High	A1.8.1.1	0.064
									Medium	A1.8.1.2	0.043
									Low	A1.8.1.3	0.021
						Interstitial moisture A1.8.2	A1.8.2	0.034	High	A1.8.2.1	0.034
									Medium	A1.8.2.2	0.023
									Low	A1.8.2.3	0.011
						Spread dampness A1.8.3	A1.8.3	0.045	High	A1.8.3.1	0.045
									Medium	A1.8.3.2	0.3
									Low	A1.8.3.3	0.015
						Moisture from condensation A1.8.4	A1.8.4	0.057	High	A1.8.4.1	0.057
									Medium	A1.8.4.2	0.038
									Low	A1.8.4.3	0.019
			Pests A1.9	A1.9	0.17	Animal excrements A1.9.1	A1.9.1	0.092			
						Presence of animals and insects A1.9.2	A1.9.2	0.078			
			Natural attack A1.10	A1.10	0.17	Presence of vegetation A1.10.1	A1.10.1	0.063			
						Biological coatings A1.10.2	A1.10.2	0.068			
						Black markings A1.10.3	A1.10.3	0.039			

Building monitoring A1.11	A1.11	0.23	Recoinnaissance survey A1.11.1	A1.11.1	0.012			
			Diagnostic survey A1.11.2	A1.11.2	0.023			
			Condition survey A1.11.3	A1.11.3	0.025			
			Structural appraisal A1.11.4	A1.11.4	0.024			
			Compatibility of use A1.11.5	A1.11.5	0.014			
			Material survey A1.11.6	A1.11.6	0.016			
			Detection of missing parts A1.11.7	A1.11.7	0.008			
			Dampness measures A1.11.8	A1.11.8	0.020			
			Site analysis A1.11.9	A1.11.9	0.018			
			Plants survey A1.11.10	A1.11.10	0.015			
			Virtual management technologies (BIM, CAD, GIS) A1.11.11	A1.11.11	0.012			
			Instability analysis A1.11.12	A1.11.12	0.022			
			Geotechnical analysis A1.11.13	A1.11.13	0.012			
			Presence of parking lots and parking areas A1.11.14	A1.11.14	0.003			
			Presence of green areas A1.11.15	A1.11.15	0.007			
Cladding A2.1	A2.1	0.14	Big surface A2.1.1	A2.1.1	0.14			
			Medium surface A2.1.2	A2.1.2	0.09			
			Small surface A2.1.3	A2.1.3	0.05			
Connection A2.2	A2.2	0.12	Single connection A2.2.1	A2.2.1	0.06	Big volume	A2.2.1.1	0.06
						Medium volume	A2.2.1.2	0.04
						Small volume	A2.2.1.3	0.02
			Multiple connections A2.2.2	A2.2.2	0.12	Big volume	A2.2.2.1	0.12
						Medium volume	A2.2.2.2	0.08
						Small volume	A2.2.2.3	0.04
Merge A2.3	A2.3	0.09	Between two buildings A2.3.1	A2.3.1	0.045	Big volume	A2.3.1.1	0.045
						Medium volume	A2.3.1.2	0.03
						Small volume	A2.3.1.3	0.015
			Between multiple buildings A2.3.2	A2.3.2	0.09	Big volume	A2.3.2.1	0.09
						Medium volume	A2.3.2.2	0.06
						Small volume	A2.3.2.3	0.03
Interior design transformation A2.4	A2.4	0.14	Building sector A2.4.1	A2.4.1	0.07	Big surface	A2.4.1.1	0.07
						Medium surface	A2.4.1.2	0.05
						Small surface	A2.4.1.3	0.02
			Entire building A2.4.2	A2.4.2	0.14	Big surface	A2.4.2.1	0.14
						Medium surface	A2.4.2.2	0.09
						Small surface	A2.4.2.3	0.05
Addition A2.5	A2.5	0.11	On a single building A2.5.1	A2.5.1	0.055	Big volume	A2.5.1.1	0.055
						Medium volume	A2.5.1.2	0.037
						Small volume	A2.5.1.3	0.018
			On multiple buildings A2.5.2	A2.5.2	0.11	Big volume	A2.5.2.1	0.11
						Medium volume	A2.5.2.2	0.073
						Small volume	A2.5.2.3	0.037
Subtraction A2.6	A2.6	0.09	On a single building A2.6.1	A2.6.1	0.045	Big volume	A1.6.1.1	0.045
						Medium volume	A1.6.1.2	0.03
						Small volume	A1.6.1.3	0.015
			On multiple buildings A2.6.2	A2.6.2	0.09	Big volume	A1.6.2.1	0.09
						Medium volume	A1.6.2.2	0.06
						Small volume	A1.6.2.3	0.03
Elevation A2.7	A2.7	0.09	Big volume	A2.7.1	0.09			
			Medium volume	A2.7.2	0.06			
			Small volume	A2.7.3	0.03			
Demolition A2.8	A2.8	0.1	Big volume	A2.8.1	0.1			
			Medium volume	A2.8.2	0.07			
			Small volume	A2.8.3	0.03			
Intrusion A2.9	A2.9	0.09	Big volume	A2.9.1	0.09			
			Medium volume	A2.9.2	0.06			
			Small volume	A2.9.3	0.03			

Stack/detach A2.10	A2.10	0.07	Vertical stack/detach A2.10.1	A2.10.1	0.035	Big volume	A2.10.1.1	0.035
						Medium volume	A2.10.1.2	0.023
						Small volume	A2.10.1.3	0.012
			Lateral stack/detach A2.10.2	A2.10.2	0.035	Big volume	A2.10.2.1	0.035
						Medium volume	A2.10.2.2	0.023
						Small volume	A2.10.2.3	0.012
Envolve/roof A2.11	A2.11	0.12	Bioclimatic intervention A2.11.1	A2.11.1	0.04	Big surface	A2.11.1.1	0.04
						Medium surface	A2.11.1.2	0.027
						Small surface	A2.11.1.3	0.013
			Skin A2.11.2	A2.11.2	0.04	Big surface	A2.11.2.1	0.04
						Medium surface	A2.11.2.2	0.027
						Small surface	A2.11.2.3	0.013
			Wrapping A2.11.3	A2.11.3	0.04	Big surface	A2.11.3.1	0.04
						Medium surface	A2.11.3.2	0.027
						Small surface	A2.11.3.3	0.013
Outside A2.12	A2.12	0.13	Big surface	A2.12.1	0.13			
			Medium surface	A2.12.2	0.09			
			Small surface	A2.12.3	0.04			
Duplication A2.13	A2.13	0.06	Big volume	A2.13.1	0.06			
			Medium volume	A2.13.2	0.04			
			Small volume	A2.13.3	0.02			
Connection with public spaces A2.14	A2.14	0.14	Big surface	A2.14.1	0.14			
			Medium surface	A2.14.2	0.09			
			Small surface	A2.14.3	0.05			
Landscape and Urban Art A2.15	A2.15	0.14	Big surface	A2.15.1	0.14			
			Medium surface	A2.15.2	0.09			
			Small surface	A2.15.3	0.05			
Testing A2.16	A2.16	0.14	Technologies A2.16.1	A2.16.1	0.021			
			Materials A2.16.2	A2.16.2	0.023			
			Plants A2.16.3	A2.16.3	0.022			
			Structural A2.16.4	A2.16.4	0.027			
			Security and domotic systems A2.16.5	A2.16.5	0.020			
			Seismic A2.16.6	A2.16.6	0.026			
			Consolidation of stone structures A2.17.1	A2.17.1	0.015	Consolidation of foundations A2.17.1.1	A2.17.1.1	0.0023
						Consolidation of walls A2.17.1.2	A2.17.1.2	0.0023
						Consolidation of archs and vaults	A2.17.1.3	0.0024

PHYSICAL DESIGN CRITERIA	A	15.38	Building shape and interventions A2	A2	2.08	Recovery interventions A2.17	A2.17	0.14				Consolidation of pillars A2.17.1.4	A2.17.1.4	0.0023
												Consolidation of vertical connectors A2.17.1.5	A2.17.1.5	0.0023
												Reconstruction of degraded parts A2.17.1.6	A2.17.1.6	0.0017
												Consolidation and preservation of historical floors A2.17.1.7	A2.17.1.7	0.0019
									Consolidation of reinforced concrete and mixed structures A2.17.2	A2.17.2	0.015	Consolidation of foundations A2.17.2.1	A2.17.2.1	0.002
												Cortical recovery of reinforced concrete elements A2.17.2.2	A2.17.2.2	0.0018
												Consolidation of pillars A2.17.2.3	A2.17.2.3	0.002
												Beams consolidation A2.17.2.4	A2.17.2.4	0.002
												Consolidation of floors A2.17.2.5	A2.17.2.5	0.002
												Consolidation of walls A2.17.2.6	A2.17.2.6	0.0018
												Consolidation of vertical connectors A2.17.2.7	A2.17.2.7	0.0018
												Reconstruction of degraded parts A2.17.2.8	A2.17.2.8	0.0015
									Dampness reduction A2.17.3	A2.17.3	0.013	Massari method A2.17.3.1	A2.17.3.1	0.0043
												Application of supporting wall A2.17.3.2	A2.17.3.2	0.0043
												Spaces ventilation A2.17.3.3	A2.17.3.3	0.0043
									Consolidation of wooden structures A2.17.4	A2.17.4	0.014	Steel reinforcements A2.17.4.1	A2.17.4.1	0.002
												Junctions reinforcement A2.17.4.2	A2.17.4.2	0.002
												Hardening of wooden slabs A2.17.4.3	A2.17.4.3	0.002
												Treatment of wood using resins	A2.17.4.4	0.002
												Insertion of steel tension rods A2.17.4.5	A2.17.4.5	0.002
												Insertion of struts A2.17.4.6	A2.17.4.6	0.002
												Regeneration of headlines with steelworks A2.17.4.7	A2.17.4.7	0.002
									Consolidation of steel structures A2.17.5	A2.17.5	0.014	Oxidation protection A2.17.5.1	A2.17.5.1	0.0035
												Removal of damaged items A2.17.5.2	A2.17.5.2	0.0035
												Structure reinforcement A2.17.5.3	A2.17.5.3	0.0035
												Fireproof and anti-corrosion paints	A2.17.5.4	0.0035

			Insertion of openings A2.17.6	A2.17.6	0.008			
			Provisional works A2.17.7	A2.17.7	0.012			
			Seismic adaptation interventions A2.17.8	A2.17.8	0.015			
			Material recovery and protection actions A2.17.9	A2.17.9	0.013			
			Restoration of existing toilets A2.17.10	A2.17.10	0.01			
			Restoration of existing plants A2.17.11	A2.17.11	0.01			
Building construction interventions A2.18	A2.18	0.11	Material extraction A2.18.1	A2.18.1	0.0042			
			Components production A2.18.2	A2.18.2	0.0041			
			Material transport A2.18.3	A2.18.3	0.0042			
			Site layout A.18.4	A2.18.4	0.0043			
			Arrangement of provisional works A2.18.5	A2.18.5	0.0041			
			Ground leveling A2.18.6	A2.18.6	0.0042			
			Foundation digging A2.18.7	A2.18.7	0.0046			
			Realization of foundations A2.18.8	A2.18.8	0.0050			
			Realization of the backbone A2.18.9	A2.18.9	0.0054			
			Realization of slabs A2.18.10	A2.18.10	0.0048			
			Realization of external vertical closures A2.18.11	A2.18.11	0.0043			
			Realization of roofing slab A2.18.12	A2.18.12	0.0046			
			Plant construction A2.18.13	A2.18.13	0.0048			
			Construction of buffer walls A2.18.14	A2.18.14	0.0035			
			Finishes A2.18.15	A2.18.15	0.0033			
			Realization of security and safety technologies A2.18.16	A2.18.16	0.0043			
			Furnitures A2.18.17	A2.18.17	0.0032			
			Realization of external finishes A2.18.18	A2.18.18	0.0037			
			Urban furniture A2.18.19	A2.18.19	0.0032			
			Urban green and planting A2.18.20	A2.18.20	0.0035			
			Waste disposal A2.18.21	A2.18.21	0.0042			
			Primary and secondary urbanization interventions A2.18.22	A2.18.22	0.0045			
			Realization of restrooms A2.18.23	A2.18.23	0.0041			
			Plants installation A2.18.24	A2.18.24	0.0047			
			Implementation of technological systems A2.18.25	A2.18.25	0.0046			
			Realization of vertical connections and ramps A2.18.26	A2.18.26	0.0046			
Excavation A2.19	A2.19	0.07	Big volume A2.19.1	A2.19.1	0.07			
			Medium volume A2.19.2	A2.19.2	0.047			
			Small volume A2.19.3	A2.19.3	0.023			
Level of pollution A3.1	A3.1	0.36	Environmental pollution A3.1.1	A3.1.1	0.094	High	A3.1.1.1	0.094
						Medium	A3.1.1.2	0.063
						Low	A3.1.1.3	0.031
			Acoustic pollution A3.1.2	A3.1.2	0.041	High	A3.1.2.1	0.041
						Medium	A3.1.2.2	0.027
						Low	A3.1.2.3	0.014
			Water pollution A3.1.3	A3.1.3	0.053	High	A3.1.3.1	0.053
						Medium	A3.1.3.2	0.035
						Low	A3.1.3.3	0.018
			Soil pollution A3.1.4	A3.1.4	0.065	High	A3.1.4.1	0.065
						Medium	A3.1.4.2	0.043
						Low	A3.1.4.3	0.022
			Light pollution A3.1.5	A3.1.5	0.017	High	A3.1.5.1	0.017
						Medium	A3.1.5.2	0.011
						Low	A3.1.5.3	0.06
			Air pollution A3.1.6	A3.1.6	0.091	High	A3.1.6.1	0.091
						Medium	A3.1.6.2	0.061
						Low	A3.1.6.3	0.03

Site conditions A3	A3	2.15	Soil type A3.2	A3.2	0.37	Unconsolidated soil A3.2.1	A3.2.1	0.37			
						Low consolidated soil A3.2.2	A3.2.2	0.30			
						Medium consolidated soil A3.2.3	A3.2.3	0.22			
						Consolidated soil A3.2.4	A3.2.4	0.15			
						High consolidated soil A3.3.5	A3.2.5	0.07			
			Presence of vegetation A3.3	A3.3	0.32	High presence of vegetation A3.3.1	A3.3.1	0.32			
						Medium presence of vegetation A3.3.2	A3.3.2	0.21			
						Low presence of vegetation A3.3.3	A3.3.3	0.11			
			Level of traffic A3.4	A3.4	0.33	Car A3.4.1	A3.4.1	0.1	High	A3.4.1.1	0.1
									Medium	A3.4.1.2	0.067
									Low	A3.4.1.3	0.033
						Camion A3.4.2	A3.4.2	0.103	High	A3.4.2.1	0.103
									Medium	A3.4.2.2	0.069
									Low	A3.4.2.3	0.034
						Ship A3.4.3	A3.4.3	0.014	High	A3.4.3.1	0.014
									Medium	A3.4.3.2	0.009
									Low	A3.4.3.3	0.005
						Motorbike A3.4.4	A3.4.4	0.016	High	A3.4.4.1	0.016
									Medium	A3.4.4.2	0.011
									Low	A3.4.4.3	0.05
						Bike A3.4.5	A3.4.5	0.003	High	A3.4.5.1	0.003
									Medium	A3.4.5.2	0.002
									Low	A3.4.5.3	0.001
						Pedestrians A3.4.6	A3.4.6	0.005	High	A3.4.6.1	0.005
									Medium	A3.4.6.2	0.003
									Low	A3.4.6.3	0.002
						Train A3.4.7	A3.4.7	0.027	High	A3.4.7.1	0.027
									Medium	A3.4.7.2	0.018
									Low	A3.4.7.3	0.09
						Airplane A3.4.8	A3.4.8	0.011	High	A3.4.8.1	0.011
									Medium	A3.4.8.2	0.007
									Low	A3.4.8.3	0.004
						Bus A3.4.9	A3.4.9	0.051	High	A3.4.9.1	0.051
									Medium	A3.4.9.2	0.034
									Low	A3.4.9.3	0.017
			Context level of decay A3.5	A3.5	0.42	Streets A3.5.1	A3.5.1	0.102	High	A3.5.1.1	0.102
									Medium	A3.5.1.2	0.068
									Low	A3.5.1.3	0.034
						Public lightning A3.5.2	A3.5.2	0.087	High	A3.5.2.1	0.087
									Medium	A3.5.2.2	0.058
									Low	A3.5.2.3	0.029
						City context A3.5.3	A3.5.3	0.112	High	A3.5.3.1	0.112
									Medium	A3.5.3.2	0.075
									Low	A3.5.3.3	0.037
						Environment A3.5.4	A3.5.4	0.119	High	A3.5.4.1	0.119
									Medium	A3.5.4.2	0.079
									Low	A3.5.4.3	0.04
			Context monitoring A3.6	A3.6	0.35	Analysis of flows and traffic A3.6.1	A3.6.1	0.044			
						Landscape analysis A3.6.2	A3.6.2	0.039			
						Analysis of the surrounding buildings A3.6.3	A3.6.3	0.030			
						Analysis of the services present A3.6.4	A3.6.4	0.050			
						Hydrogeological analysis A3.6.5	A3.6.5	0.026			
						Reconnaissance of the neighborhood A3.6.6	A3.6.6	0.021			
						Town planning analysis A3.6.7	A3.6.7	0.035			
						Analysis of parking areas A3.6.8	A3.6.8	0.021			
						Analysis of urban infrastructures A3.6.9	A3.6.9	0.045			
						Analysis of green areas A3.6.10	A3.6.10	0.038			

Climate factors and hazards A4	A4	1.57	Air humidity A4.1	A4.1	0.11	High level of humidity	A4.1.1	0.11
						Medium level of humidity	A4.1.2	0.07
						Low level of humidity	A4.1.3	0.04
			Snow A4.2	A4.2	0.12	Strong snowfall	A4.2.1	0.12
						Medium snowfall	A4.2.2	0.08
						Weak snowfall	A4.2.3	0.04
			Rain A4.3	A4.3	0.11	Strong rainfall	A4.3.1	0.11
						Medium rainfall	A4.3.2	0.07
						Weak rainfall	A4.3.3	0.04
			Sun A4.4	A4.4	0.09	High light intensity	A4.4.1	0.09
						Medium light intensity	A4.4.2	0.06
						Low light intensity	A4.4.3	0.03
			Wind A4.5	A4.5	0.11	Strong winds	A4.5.1	0.11
						Medium winds	A4.5.2	0.07
						Weak winds	A4.5.3	0.04
			Temperature fluctuations A4.6	A4.6	0.13	High fluctuation	A4.6.1	0.13
						Medium fluctuation	A4.6.2	0.08
						Low fluctuation	A4.6.3	0.05
			Seismic zone A4.7	A4.7	0.18	High danger	A4.7.1	0.18
						Medium danger	A4.7.2	0.12
						Low danger	A4.7.3	0.06
			Area with flood and storm surge hazards A4.8	A4.8	0.18	High danger	A4.8.1	0.18
						Medium danger	A4.8.2	0.12
						Low danger	A4.8.3	0.06
			Area with landslide hazards A4.9	A4.9	0.18	High danger	A4.9.1	0.18
						Medium danger	A4.9.2	0.12
						Low danger	A4.9.3	0.06
			Avalanche danger zone A4.10	A4.10	0.18	High danger	A4.10.1	0.18
						Medium danger	A4.10.2	0.12
						Low danger	A4.10.3	0.06
			Typhoon danger zone A4.11	A4.11	0.17	High danger	A4.11.1	0.17
						Medium danger	A4.11.2	0.11
						Low danger	A4.11.3	0.06
Building dimensions A5	A5	1.69	Covered surface A5.1	A5.1	0.35	High A5.1.1	A5.1.1	0.35
						Medium A5.1.2	A5.1.2	0.23
						Low A5.1.3	A5.1.3	0.12
			Volumes A5.2	A5.2	0.39	High A5.2.1	A5.2.1	0.39
						Medium A5.2.2	A5.2.2	0.26
						Low A5.2.3	A5.2.3	0.13
			Total surface A5.3	A5.3	0.34	High A5.3.1	A5.3.1	0.34
						Medium A5.3.2	A5.3.2	0.22
						Low A5.3.3	A5.3.3	0.12
			Glazed surfaces A5.4	A5.4	0.3	High A5.4.1	A5.4.1	0.3
						Medium A5.4.2	A5.4.2	0.2
						Low A5.4.3	A5.4.3	0.1
			Number of floors A5.5	A5.5	0.31	High A5.5.1	A5.5.1	0.31
						Medium A5.5.2	A5.5.2	0.2
						Low A5.5.3	A5.5.3	0.11
Orientation A6	A6	1.58	North A6.1	A6.1	0.39			
			North-East A6.2	A6.2	0.24			
			North-West A6.3	A6.3	0.25			
			East A6.4	A6.4	0.08			
			West A6.5	A6.5	0.12			
			South A6.6	A6.6	0.19			
			South-East A6.7	A6.7	0.17			
			South-West A6.8	A6.8	0.14			

			South-East A6.7	A6.7	0.17			
			South-West A6.8	A6.8	0.14			
Reclamation interventions A7	A7	2.03	Soil A7.1	A7.1	0.53			
			Building A7.2	A7.2	0.5			
			Air A7.3	A7.3	0.47			
			Environment A7.4	A7.4	0.53			
Maintenance interventions A8	A8	2.09	Building maintenance activities A8.1	A8.1	0.78	Ordinary maintenance A8.1.1	A8.1.1	0.398
						Extraordinary maintenance A8.1.2	A8.1.2	0.382
			External areas maintenance activities A8.2	A8.2	0.65	Pavement maintenance A8.2.1	A8.2.1	0.155
						Maintenance of green areas A8.2.2	A8.2.2	0.155
						Plants maintenance A8.2.3	A8.2.3	0.2
						Furnitures maintenance A8.2.4	A8.2.4	0.14
			Infrastructure maintenance activities A8.3	A8.3	0.67	Streets maintenance A8.3.1	A8.3.1	0.177
						Public lighting maintenance A8.3.2	A8.3.2	0.169
						Sidewalk and bicyle lane maintenance A8.3.3	A8.3.3	0.176
						Fence maintenance A8.3.4	A8.3.4	0.148

Category	Code	Weight (%)	Attributes	Code	Weight (%)	Sub-attributes 1	Code	Weight (%)	Sub-attributes 2	Code	Weight (%)	Activities	Code	Weight (%)
						Transport B1.1	B1.1	0.38	Boat/ship B1.1.1	B1.1.1	0.08	High costs	B1.1.1.1	0.08
												Medium costs	B1.1.1.2	0.053
												Low costs	B1.1.1.3	0.027
									Car B1.1.2	B1.1.2	0.067	High costs	B1.1.2.1	0.067
												Medium costs	B1.1.2.2	0.045
												Low costs	B1.1.2.3	0.022
									Camion B1.1.3	B1.1.3	0.073	High costs	B1.1.3.1	0.073
												Medium costs	B1.1.3.2	0.049
												Low costs	B1.1.3.3	0.024
									Train B1.1.4	B1.1.4	0.07	High costs	B1.1.4.1	0.07
												Medium costs	B1.1.4.2	0.047
												Low costs	B1.1.4.3	0.023
									Airplane B1.1.5	B1.1.5	0.09	High costs	B1.1.5.1	0.09
												Medium costs	B1.1.5.2	0.06
												Low costs	B1.1.5.3	0.03
						Laborer B1.2	B1.2	0.41	Workers B1.2.1	B1.2.1	0.02	High costs	B1.2.1.1	0.02
												Medium costs	B1.2.1.2	0.013
												Low costs	B1.2.1.3	0.007
									Technicians B1.2.2	B1.2.2	0.02	High costs	B1.2.2.1	0.02
												Medium costs	B1.2.2.2	0.013
												Low costs	B1.2.2.3	0.007
									Architects B1.2.3	B1.2.3	0.022	High costs	B1.2.3.1	0.022
												Medium costs	B1.2.3.2	0.015
												Low costs	B1.2.3.3	0.007
									Engineers B1.2.4	B1.2.4	0.024	High costs	B1.2.4.1	0.024
												Medium costs	B1.2.4.2	0.016
												Low costs	B1.2.4.3	0.008
									Project manager B1.2.5	B1.2.5	0.023	High costs	B1.2.5.1	0.023
												Medium costs	B1.2.5.2	0.015
												Low costs	B1.2.5.3	0.008
									Lawyers B1.2.6	B1.2.6	0.02	High costs	B1.2.6.1	0.02
												Medium costs	B1.2.6.2	0.013
												Low costs	B1.2.6.3	0.007
									Developers B1.2.7	B1.2.7	0.023	High costs	B1.2.7.1	0.023
												Medium costs	B1.2.7.2	0.015
												Low costs	B1.2.7.3	0.008
									Designers B1.2.8	B1.2.8	0.022	High costs	B1.2.8.1	0.022
												Medium costs	B1.2.8.2	0.015
												Low costs	B1.2.8.3	0.007
									Surveyors B1.2.9	B1.2.9	0.017	High costs	B1.2.9.1	0.017
												Medium costs	B1.2.9.2	0.011
												Low costs	B1.2.9.3	0.006
									Marketeers B1.2.10	B1.2.10	0.016	High costs	B1.2.10.1	0.016
												Medium costs	B1.2.10.2	0.011
												Low costs	B1.2.10.3	0.005
									Inventors B1.2.11	B1.2.11	0.019	High costs	B1.2.11.1	0.019
												Medium costs	B1.2.11.2	0.013
												Low costs	B1.2.11.3	0.006
									Graphic designers B1.2.12	B1.2.12	0.017	High costs	B1.2.12.1	0.017
												Medium costs	B1.2.12.2	0.011
												Low costs	B1.2.12.3	0.006
									Employees B1.2.13	B1.2.13	0.015	High costs	B1.2.13.1	0.015
												Medium costs	B1.2.13.2	0.01
												Low costs	B1.2.13.3	0.005
									Archaeologists B1.2.14	B1.2.14	0.017	High costs	B1.2.14.1	0.017
												Medium costs	B1.2.14.2	0.011
												Low costs	B1.2.14.3	0.006
									IT engineers B1.2.15	B1.2.15	0.016	High costs	B1.2.15.1	0.016
												Medium costs	B1.2.15.2	0.011
												Low costs	B1.2.15.3	0.005
									Urban planners and landscapers B1.2.16	B1.2.16	0.02	High costs	B1.2.16.1	0.02
												Medium costs	B1.2.16.2	0.013
												Low costs	B1.2.16.3	0.007
									Executives and managers B1.2.17	B1.2.17	0.022	High costs	B1.2.17.1	0.022
												Medium costs	B1.2.17.2	0.015
												Low costs	B1.2.17.3	0.007
									Administrative and political figures B1.2.18	B1.2.18	0.018	High costs	B1.2.18.1	0.018
												Medium costs	B1.2.18.2	0.012
												Low costs	B1.2.18.3	0.006
									Construction companies B1.2.19	B1.2.19	0.021	High costs	B1.2.19.1	0.021
												Medium costs	B1.2.19.2	0.014
												Low costs	B1.2.19.3	0.007
									Professors and historians of architecture B1.2.20	B1.2.20	0.012	High costs	B1.2.20.1	0.012
												Medium costs	B1.2.20.2	0.008
												Low costs	B1.2.20.3	0.004
									Sociologists B1.2.21	B1.2.21	0.011	High costs	B1.2.21.1	0.011
												Medium costs	B1.2.21.2	0.007
												Low costs	B1.2.21.3	0.004
									Promoters and sponsor B1.2.22	B1.2.22	0.016	High costs	B1.2.22.1	0.016
												Medium costs	B1.2.22.2	0.011
												Low costs	B1.2.22.3	0.005

ECONOMIC DESIGN CRITERIA B	B	14.82	Costs B1	B1	5.06	Maintenance work B1.3	B1.3	0.46	Ordinary maintenance costs B1.3.1	B1.3.1	0.111	High costs	B1.3.1.1	0.111
												Medium costs	B1.3.1.2	0.074
												Low costs	B1.3.1.3	0.037
									Extraordinary maintenance costs B1.3.2	B1.3.2	0.137	High costs	B1.3.2.1	0.137
												Medium costs	B1.3.2.2	0.091
												Low costs	B1.3.2.3	0.046
									Extrernal areas maintenance costs B1.3.3	B1.3.3	0.099	High costs	B1.3.3.1	0.099
												Medium costs	B1.3.3.2	0.066
												Low costs	B1.3.3.3	0.033
									Infrastructure maintenance costs B1.3.4	B1.3.4	0.114	High costs	B1.3.4.1	0.114
												Medium costs	B1.3.4.2	0.076
												Low costs	B1.3.4.3	0.038
						Reclamation costs B1.4	B1.4	0.45	Building reclamation B1.4.1	B1.4.1	0.106	High costs	B1.4.1.1	0.106
												Medium costs	B1.4.1.2	0.071
												Low costs	B1.4.1.3	0.035
									Soil reclamation B1.4.2	B1.4.2	0.116	High costs	B1.4.2.1	0.116
												Medium costs	B1.4.2.2	0.077
												Low costs	B1.4.2.3	0.039
									Environmental reclamation B1.4.3	B1.4.3	0.117	High costs	B1.4.3.1	0.117
												Medium costs	B1.4.3.2	0.077
												Low costs	B1.4.3.3	0.04
									Air reclamation B1.4.4	B1.4.4	0.111	High costs	B1.4.4.1	0.11
												Medium costs	B1.4.4.2	0.074
												Low costs	B1.4.4.3	0.037
						Materials costs B1.5	B1.5	0.43	New materials B1.5.1	B1.5.1	0.107	High costs	B1.5.1.1	0.107
												Medium costs	B1.5.1.2	0.071
												Low costs	B1.5.1.3	0.036
									Recovery of existent materials B1.5.2	B1.5.2	0.102	High costs	B1.5.2.1	0.102
												Medium costs	B1.5.2.2	0.068
												Low costs	B1.5.2.3	0.034
									Raw material extraction costs B1.5.3	B1.5.3	0.104	High costs	B1.5.3.1	0.104
												Medium costs	B1.5.3.2	0.069
												Low costs	B1.5.3.3	0.035
									Raw material processing costs B1.5.4	B1.5.4	0.116	High costs	B1.5.4.1	0.116
												Medium costs	B1.5.4.2	0.077
												Low costs	B1.5.4.3	0.039
						Design costs B1.6	B1.6	0.46	Plants costs B1.6.1	B1.6.1	0.047	High costs	B1.6.1.1	0.047
												Medium costs	B1.6.1.2	0.031
												Low costs	B1.6.1.3	0.016
									Building project cost B1.6.2	B1.6.2	0.047	High costs	B1.6.2.1	0.047
												Medium costs	B1.6.2.2	0.031
												Low costs	B1.6.2.3	0.016
									Masterplan idea cost B1.6.3	B1.6.3	0.04	High costs	B1.6.3.1	0.04
												Medium costs	B1.6.3.2	0.027
												Low costs	B1.6.3.3	0.013
									Demolition cost B1.6.4	B1.6.4	0.045	High costs	B1.6.4.1	0.045
												Medium costs	B1.6.4.2	0.03
												Low costs	B1.6.4.3	0.015
									Construction cost B1.6.5	B1.6.5	0.052	High costs	B1.6.5.1	0.052
												Medium costs	B1.6.5.2	0.035
												Low costs	B1.6.5.3	0.017
									Site expropriation costs B1.6.6	B1.6.6	0.042	High costs	B1.6.6.1	0.042
												Medium costs	B1.6.6.2	0.028
												Low costs	B1.6.6.3	0.014
									Recovery interventions costs B1.6.7	B1.6.7	0.053	High costs	B1.6.7.1	0.053
												Medium costs	B1.6.7.2	0.035
												Low costs	B1.6.7.3	0.018
									Costs of provisional works B1.6.8	B1.6.8	0.038	High costs	B1.6.8.1	0.038
												Medium costs	B1.6.8.2	0.025
												Low costs	B1.6.8.3	0.013
									Primary and secondary urbanization interventions B1.6.9	B1.6.9	0.045	High costs	B1.6.9.1	0.045
												Medium costs	B1.6.9.2	0.03
												Low costs	B1.6.9.3	0.015
									Costs of the technological solutions adopted B1.6.10	B1.6.10	0.049	High costs	B1.6.10.1	0.049
												Medium costs	B1.6.10.2	0.033
												Low costs	B1.6.10.3	0.016
						Bureaucratic costs B1.7	B1.7	0.37	Costs of administrative procedures B1.7.1	B1.7.1	0.183	High costs	B1.7.1.1	0.183
												Medium costs	B1.7.1.2	0.122
												Low costs	B1.7.1.3	0.061
									Implementation costs of recovery plans B1.7.2	B1.7.2	0.187	High costs	B1.7.2.1	0.187
												Medium costs	B1.7.2.2	0.125
												Low costs	B1.7.2.3	0.062

			Building monitoring costs B1.8	B1.8	0.39	Photogrammetry B1.8.1	B1.8.1	0.049	High costs	B1.8.1.1	0.049
									Medium costs	B1.8.1.2	0.033
									Low costs	B1.8.1.3	0.016
						Laser scanner B1.8.2	B1.8.2	0.06	High costs	B1.8.2.1	0.06
									Medium costs	B1.8.2.2	0.04
									Low costs	B1.8.2.3	0.02
						Architectural survey B1.8.3	B1.8.3	0.051	High costs	B1.8.3.1	0.051
									Medium costs	B1.8.3.2	0.034
									Low costs	B1.8.3.3	0.017
						Measurements activities B1.8.4	B1.8.4	0.047	High costs	B1.8.4.1	0.047
									Medium costs	B1.8.4.2	0.031
									Low costs	B1.8.4.3	0.016
						Thermo-igrometric detections B1.8.5	B1.8.5	0.058	High costs	B1.8.5.1	0.058
									Medium costs	B1.8.5.2	0.039
									Low costs	B1.8.5.3	0.019
						Testing B1.8.6	B1.8.6	0.064	High costs	B1.8.6.1	0.064
									Medium costs	B1.8.6.2	0.043
									Low costs	B1.8.6.3	0.021
						Archaeological surveys B1.8.7	B1.8.7	0.061	High costs	B1.8.7.1	0.061
									Medium costs	B1.8.7.2	0.04
									Low costs	B1.8.7.3	0.021
			Unexpected costs B1.9	B1.9	0.42	High costs	B1.9.1	0.42			
						Medium costs	B1.9.2	0.28			
						Low costs	B1.9.3	0.14			
			Waste disposal costs B1.10	B1.10	0.39	High costs	B1.10.1	0.39			
						Medium costs	B1.10.2	0.26			
						Low costs	B1.10.3	0.13			
			Technical and general costs B1.11	B1.11	0.41	High costs	B1.11.1	0.41			
						Medium costs	B1.11.2	0.28			
						Low costs	B1.11.3	0.14			
			Costs for interventions of structure seismic adaptation B1.12	B1.12	0.48	High costs	B1.12.1	0.48			
						Medium costs	B1.12.2	0.32			
						Low costs	B1.12.3	0.16			
Market influence B2	B2	4.77	Life quality B2.1	B2.1	0.63	High quality	B2.1.1	0.21			
						Medium quality	B2.1.2	0.42			
						Low quality	B2.1.3	0.63			
			Demand B2.2	B2.2	0.63	High demand	B2.2.1	0.21			
						Medium demand	B2.2.2	0.42			
						Low demand	B2.2.3	0.63			
			Building supply B2.3	B2.3	0.51	High supply	B2.3.1	0.17			
						Medium supple	B2.3.2	0.34			
						Low supply	B2.3.3	0.51			
			Number of consumers involved B2.4	B2.4	0.57	High	B2.4.1	0.19			
						Medium	B2.4.2	0.38			
						Low	B2.4.3	0.57			
			Occupiers requirements and expectations B2.5	B2.5	0.57	High expectations	B2.5.1	0.19			
						Medium expectations	B2.5.2	0.38			
						Low expectations	B2.5.3	0.57			
			Job opportunity B2.6	B2.6	0.61	High	B2.6.1	0.2			
						Medium	B2.6.2	0.41			
						Low	B2.6.3	0.61			
			Profitability B2.7	B2.7	0.64	High	B2.7.1	0.22			
						Medium	B2.7.2	0.42			
						Low	B2.7.3	0.64			
			Economic feasibility B2.8	B2.8	0.61	High	B2.8.1	0.2			
						Medium	B2.8.2	0.41			
						Low	B2.8.3	0.61			
Financial investments B3	B3	4.98	Public B3.1	B3.1	2.49	High	B3.1.1	0.83			
						Medium	B3.1.2	1.66			
						Low	B3.1.3	2.49			
			Private B3.2	B3.2	2.49	High	B3.2.1	0.83			
						Medium	B3.2.2	1.66			
						Low	B3.2.3	2.49			

Category	Code	Weight (%)	Attributes	Code	Weight (%)	Sub-attributes 1	Code	Weight (%)	Sub-attributes 2	Code	Weight (%)	Activities	Code	Weight (%)
ONAL DESIGN CRITERIA C	C	16.24	Spatial Flow C1	C1	4.17	External paths C1.1	C1.1	0.77	High flow	C1.1.1	0.77			
									Medium flow	C1.1.2	0.51			
									Low flow	C1.1.3	0.26			
						Internal paths C1.2	C1.2	0.86	High flow	C1.2.1	0.86			
									Medium flow	C1.2.2	0.57			
									Low flow	C1.2.3	0.29			
						Vertical connectors C1.3	C1.3	0.91	High flow	C1.3.1	0.91			
									Medium flow	C1.3.2	0.61			
									Low flow	C1.3.3	0.3			
						Escape paths C1.4	C1.4	0.81	High flow	C1.4.1	0.81			
									Medium flow	C1.4.2	0.54			
									Low flow	C1.4.3	0.27			
						Building connectivity C1.5	C1.5	0.82	Points of interest C1.5.1	C1.5.1	0.25	High connectivity	C1.5.1.1	0.08
												Medium connectivity	C1.5.1.2	0.17
												Low connectivity	C1.5.1.3	0.25
									Parking areas/public spaces/green areas C1.5.2	C1.5.2	0.234	High connectivity	C1.5.2.1	0.078
												Medium connectivity	C1.5.2.2	0.156
												Low connectivity	C1.5.2.3	0.234
									City centre C1.5.3	C1.5.3	0.156	High connectivity	C1.5.3.1	0.052
												Medium connectivity	C1.5.3.2	0.104
												Low connectivity	C1.5.3.3	0.156
									Waterfront C1.5.4	C1.5.4	0.062	High connectivity	C1.5.4.1	0.021
												Medium connectivity	C1.5.4.2	0.041
												Low connectivity	C1.5.4.3	0.062
									Main services C1.5.5	C1.5.5	0.117	High connectivity	C1.5.5.1	0.039
												Medium connectivity	C1.5.5.2	0.078
												Low connectivity	C1.5.5.3	0.117
			Building flexibility and convertibility C2	C2	4.33	Building C2.1	C2.1	2.27	High flexibility	C2.1.1	0.76			
									Medium flexibility	C2.1.2	1.51			
									Low flexibility	C2.1.3	2.27			
						Building site C2.2	C2.2	2.06	High flexibility	C2.2.1	0.69			
									Medium flexibility	C2.2.2	1.37			
									Low flexibility	C2.2.3	2.06			
			Building disassembly C3	C3	3.6	High level of disassembly	C3.1	1.2						
						Medium level of disassembly	C3.2	2.4						
						Low level of disassembly	C3.3	3.6						
						Cultural C4.1	C4.1	0.44	Conference center C4.1.1	C4.1.1	0.031			
									Theater C4.1.2	C4.1.2	0.034			
									Concert hall C4.1.3	C4.1.3	0.034			
									Museum C4.1.4	C4.1.4	0.039			
									Exhibition spaces C4.1.5	C4.1.5	0.036			
									Cinema C4.1.6	C4.1.6	0.024			
									Library C4.1.7	C4.1.7	0.039			
									University lab C4.1.8	C4.1.8	0.037			
									Student center C4.1.9	C4.1.9	0.029			
									School lab C4.1.10	C4.1.10	0.021			
									Biocenter C4.1.11	C4.1.11	0.010			
									Science laboratories C4.1.12	C4.1.12	0.016			
									Research center C4.1.13	C4.1.13	0.024			
									FabLab C4.1.14	C4.1.14	0.028			
									Cultural Center C4.1.15	C4.1.15	0.037			
						Residential C4.2	C4.2	0.37	Mixed-use C4.2.1	C4.2.1	0.058			
									Social housing C4.2.2	C4.2.2	0.075			
									Luxury apartments C4.2.3	C4.2.3	0.014			
									Villa C4.2.4	C4.2.4	0.014			
									Students rooms C4.2.5	C4.2.5	0.061			
									Hotel C4.2.6	C4.2.6	0.022			
									Co-housing C4.2.7	C4.2.7	0.044			
									Hostel C4.2.8	C4.2.8	0.030			
									Home for the elderly C4.2.9	C4.2.9	0.022			
									Condominium C4.2.10	C4.2.10	0.030			
						Religious C4.3	C4.3	0.2	Church C4.3.1	C4.3.1	0.042			
									Abbey C4.3.2	C4.3.2	0.017			
									Convent C4.3.3	C4.3.3	0.058			
									Religious institutions C4.3.4	C4.3.4	0.083			
						Commercial C4.4	C4.4	0.42	Shopping center C4.4.1	C4.4.1	0.034			
									Showroom C4.4.2	C4.4.2	0.032			
									Bar C4.4.3	C4.4.3	0.032			
									Restaurant C4.4.4	C4.4.4	0.038			
									Vertical farm C4.4.5	C4.4.5	0.034			
									Supermarket C4.4.6	C4.4.6	0.022			
									Shops C4.4.7	C4.4.7	0.030			
									Backery C4.4.8	C4.4.8	0.014			
									Pub C4.4.9	C4.4.9	0.030			
									Fair C4.4.10	C4.4.10	0.032			
									Greenhouses C4.4.11	C4.4.11	0.014			
									Distillery C4.4.12	C4.4.12	0.030			
									Retail C4.4.13	C4.4.13	0.020			
									Bookshop C4.4.14	C4.4.14	0.028			
									Florist C4.4.15	C4.4.15	0.026			

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Services and usage C4	C4	4.14	Offices C4.5	C4.5	0.4	Co-working spaces C4.5.1	C4.5.1	0.048
						Hubs C4.5.2	C4.5.2	0.035
						Banks C4.5.3	C4.5.3	0.010
						Newspapers offices C4.5.4	C4.5.4	0.015
						Post C4.5.5	C4.5.5	0.013
						Call center C4.5.6	C4.5.6	0.015
						Smart office C4.5.7	C4.5.7	0.028
						Architectural studio C4.5.8	C4.5.8	0.031
						Engineering studio C4.5.9	C4.5.9	0.033
						Archive C4.5.10	C4.5.10	0.018
						Public institutions C4.5.11	C4.5.11	0.018
						Mechanical workshop C4.5.12	C4.5.12	0.010
						Artist studio C4.5.13	C4.5.13	0.023
						Photographic studio C4.5.14	C4.5.14	0.018
						Storage C4.5.15	C4.5.15	0.013
						Garage C4.5.16	C4.5.16	0.008
						Law firm C4.5.17	C4.5.17	0.018
						Computer and graphic design studio C4.5.18	C4.5.18	0.025
						Animation studio C4.5.19	C4.5.19	0.021
			Sporty C4.6	C4.6	0.39	Stadium C4.6.1	C4.6.1	0.032
						Gym C4.6.2	C4.6.2	0.068
						Sport center C4.6.3	C4.6.3	0.072
						Playground C4.6.4	C4.6.4	0.079
						Skatepark C4.6.5	C4.6.5	0.057
						Dancing school C4.6.6	C4.6.6	0.039
						Climbing center C4.6.7	C4.6.7	0.043
			Education C4.7	C4.7	0.39	Asylum C4.7.1	C4.7.1	0.019
						Primary school C4.7.2	C4.7.2	0.013
						Secondary school C4.7.3	C4.7.3	0.012
						High school C4.7.4	C4.7.4	0.018
						University / College C4.7.5	C4.7.5	0.034
						Language school C4.7.6	C4.7.6	0.018
						Acting school C4.7.7	C4.7.7	0.021
						Music school C4.7.8	C4.7.8	0.024
						Singing school C4.7.9	C4.7.9	0.021
						Academy of fine arts C4.7.10	C4.7.10	0.030
						Arts and crafts workshop C4.7.11	C4.7.11	0.024
						Workshop C4.7.12	C4.7.12	0.033
						Photographic school C4.7.13	C4.7.13	0.013
						ArtLab C4.7.14	C4.7.14	0.024
						Educational farm C4.7.15	C4.7.15	0.013
						Job training center C4.7.16	C4.7.16	0.019
						Education center C4.7.17	C4.7.17	0.018
						Cooking school C4.7.18	C4.7.18	0.015
						Fashion academy C4.7.19	C4.7.19	0.013
			Spaces for fun C4.8	C4.8	0.42	Disco C4.8.1	C4.8.1	0.059
						Game room C4.8.2	C4.8.2	0.050
						Bowling C4.8.3	C4.8.3	0.041
						Theme park C4.8.4	C4.8.4	0.086
						Go-kart racetrack C4.8.5	C4.8.5	0.041
						Open-air event space C4.8.6	C4.8.6	0.117
						Casinò C4.8.7	C4.8.7	0.027
			Public spaces C4.9	C4.9	0.43	Park C4.9.1	C4.9.1	0.085
						Garden C4.9.2	C4.9.2	0.046
						Square C4.9.3	C4.9.3	0.082
						Arena C4.9.4	C4.9.4	0.050
						Community center C4.9.5	C4.9.5	0.036
						Meeting rooms C4.9.6	C4.9.6	0.032
						Dog park C4.9.7	C4.9.7	0.050
						Parking areas C4.9.8	C4.9.8	0.050
			Spaces for healthcare C4.10	C4.10	0.34	Hospital C4.10.1	C4.10.1	0.028
						Medical center C4.10.2	C4.10.2	0.038
						Nursing home C4.10.3	C4.10.3	0.038
						Analysis center C4.10.4	C4.10.4	0.023
						Dental center C4.10.5	C4.10.5	0.016
						Halfway house C4.10.6	C4.10.6	0.035
						Pharmacy C4.10.7	C4.10.7	0.021
						Radiological laboratory C4.10.8	C4.10.8	0.019
						Beauty salon C4.10.9	C4.10.9	0.035
						Animal hospital C4.10.10	C4.10.10	0.030
						Spa C4.10.11	C4.10.11	0.056
			Spaces for children C4.11	C4.11	0.35	Toy library C4.11.1	C4.11.1	0.138
						Adventure playground C4.11.2	C4.11.2	0.098
						Kids playground C4.11.3	C4.11.3	0.115

Category	Code	Weight (%)	Attributes	Code	Weight (%)	Sub-attributes 1	Code	Weight (%)	Sub-attributes 2	Code	Weight (%)
			Materials D1	D1	3.11	Natural materials D1.1	D1.1	0.37	Kenaf D1.1.1	D1.1.1	0.008
									Wood D1.1.2	D1.1.2	0.026
									Straw D1.1.3	D1.1.3	0.014
									Hempcrete/Hemp D1.1.4	D1.1.4	0.018
									Bamboo D1.1.5	D1.1.5	0.011
									Cork D1.1.6	D1.1.6	0.018
									Lime D1.1.7	D1.1.7	0.016
									Sand D1.1.8	D1.1.8	0.025
									Terracotta D1.1.9	D1.1.9	0.016
									Gravel D1.1.10	D1.1.10	0.021
									Plant fiber D1.1.11	D1.1.11	0.007
									Stone D1.1.12	D1.1.12	0.029
									Unbaked clay D1.1.13	D1.1.13	0.007
									Wool D1.1.14	D1.1.14	0.008
									Expanded clay D1.1.15	D1.1.15	0.021
									Cross-laminated timber D1.1.16	D1.1.16	0.028
									Natural clay/Clay D1.1.17	D1.1.17	0.022
									Juta D1.1.18	D1.1.18	0.006
									Coconut D1.1.19	D1.1.19	0.011
									Bio-materials D1.1.20	D1.1.20	0.016
									Plywood D1.1.21	D1.1.21	0.023
									Rammed earth D1.1.22	D1.1.22	0.009
									Mycelium D1.1.23	D1.1.23	0.009
						Recycled materials D1.2	D1.2	0.39	Recycled paper D1.2.1	D1.2.1	0.070
									Recycled plastic D1.2.2	D1.2.2	0.083
									Recycled wood D1.2.3	D1.2.3	0.114
									Recycled metal D1.2.4	D1.2.4	0.123
						Metallic materials D1.3	D1.3	0.35	Carbon D1.3.1	D1.3.1	0.021
									Perlite D1.3.2	D1.3.2	0.017
									Cor-ten D1.3.3	D1.3.3	0.033
									Iron D1.3.4	D1.3.4	0.026
									Copper D1.3.5	D1.3.5	0.024
									Steel D1.3.6	D1.3.6	0.038
									Aluminium D1.3.7	D1.3.7	0.034
									Bronze D1.3.8	D1.3.8	0.016
									Titanium D1.3.9	D1.3.9	0.018
									Lead D1.3.10	D1.3.10	0.013
									Cast iron D1.3.11	D1.3.11	0.020
									Brass D1.3.12	D1.3.12	0.011
									Cupro-nichel D1.3.13	D1.3.13	0.008
									Cupro-aluminium D1.3.14	D1.3.14	0.009
									Zinc D1.3.15	D1.3.15	0.012
									Galvanized steel D1.3.16	D1.3.16	0.026
									Ferrock D1.3.17	D1.3.17	0.022
						Cementitius Materials D1.4	D1.4	0.24	Concrete D1.4.1	D1.4.1	0.056
									Lightweight concrete D1.4.2	D1.4.2	0.051
									Fiber-reinforced concrete D1.4.3	D1.4.3	0.060
									Self-healing concrete D1.4.4	D1.4.4	0.039
									Photocatalytic concrete D1.4.5	D1.4.5	0.034
						Stone materials D1.5	D1.5	0.27	Gres D1.5.1	D1.5.1	0.047
									Brick D1.5.2	D1.5.2	0.049
									Granite D1.5.3	D1.5.3	0.036
									Pumice D1.5.4	D1.5.4	0.038
									Tuff D1.5.5	D1.5.5	0.040
									Marble D1.5.6	D1.5.6	0.033
									Pottery D1.5.7	D1.5.7	0.027
						Fibrous materials D1.6	D1.6	0.3	Paper D1.6.1	D1.6.1	0.017
									Rock wool D1.6.2	D1.6.2	0.068
									Glass wool D1.6.3	D1.6.3	0.060
									Cellulose fibre D1.6.4	D1.6.4	0.045
									Flax fibre D1.6.5	D1.6.5	0.020
									Fibre of polyethylene D1.6.6	D1.6.6	0.028
									Wood fibre D1.6.7	D1.6.7	0.051

TECHNOLOGICAL DESIGN CRITERIA D	D	15.04				Glassy materials D1.7	D1.7	0.28	Glass D1.7.1	D1.7.1	0.043
									Laminated glass D1.7.2	D1.7.2	0.049
									Low-emissive glass D1.7.3	D1.7.3	0.053
									Reflective glass D1.7.4	D1.7.4	0.034
									Spectrally selective glazing D1.7.5	D1.7.5	0.025
									Thermochromic glass D1.7.6	D1.7.6	0.040
									Electrochromic glass D1.7.7	D1.7.7	0.030
									Photochromic glass D1.7.8	D1.7.8	0.026
						Plastic materials D1.8	D1.8	0.28	EPS D1.8.1	D1.8.1	0.029
									XPS D1.8.2	D1.8.2	0.033
									PVC D1.8.3	D1.8.3	0.030
									Polyethylene and polypropylene sheaths D1.8.4	D1.8.4	0.024
									Polyurethane D1.8.5	D1.8.5	0.028
									Epoxy fibers D1.8.6	D1.8.6	0.026
									Epoxy and phenolic resins D1.8.7	D1.8.7	0.027
									Polycarbonate D1.8.8	D1.8.8	0.022
									Polystyrene D1.8.9	D1.8.9	0.023
									BTS D1.8.10	D1.8.10	0.018
									Methacrylate D1.8.11	D1.8.11	0.019
						Smart materials D1.9	D1.9	0.36	Nano materials D1.9.1	D1.9.1	0.109
									Phase change materials (PCMs) D1.9.2	D1.9.2	0.122
									Energy exchanging materials D1.9.3	D1.9.3	0.129
						Other materials D1.10	D1.10	0.28	Linoleum D1.10.1	D1.10.1	0.020
									Glue D1.10.2	D1.10.2	0.019
									Expanded vermiculite D1.10.3	D1.10.3	0.021
									Self-cleaning paint D1.10.4	D1.10.4	0.019
									Antibacterial paint D1.10.5	D1.10.5	0.013
									Bituminous waterprofing D1.10.6	D1.10.6	0.015
									Neoprene D1.10.7	D1.10.7	0.021
									Aerogel D1.10.8	D1.10.8	0.019
									Additives D1.10.9	D1.10.9	0.024
									Vacuum Insulation Panels D1.10.10	D1.10.10	0.013
									Hydro-NMOxide D1.10.11	D1.10.11	0.012
									Plaster D1.10.12	D1.10.12	0.024
									Mortar D1.10.13	D1.10.13	0.024
									Fireproof paint D1.10.14	D1.10.14	0.023
									Corian D1.10.15	D1.10.15	0.012
			Safety & security systems D2	D2	2.82	Alarm system D2.1	D2.1	0.64			
						Domotic system D2.2	D2.2	0.77	Switching lights on and off D2.2.1	D2.2.1	0.087
									Switching the appliances on and off D2.2.2	D2.2.2	0.083
									Electronic shield control D2.2.3	D2.2.3	0.098
									Sensors D2.2.4	D2.2.4	0.104
									Alarm clock D2.2.5	D2.2.5	0.052
									Remote control of technologies D2.2.6	D2.2.6	0.085
									Videophone D2.2.7	D2.2.7	0.073
									Central locking D2.2.8	D2.2.8	0.081
									Heating, cooling and dehumidification D2.2.9	D2.2.9	0.106
						Cameras D2.3	D2.3	0.67			
						Sensors information D2.4	D2.4	0.73	Humidity D2.4.1	D2.4.1	0.074
									Temperature indoor D2.4.2	D2.4.2	0.072
									Temperature outdoor D2.4.3	D2.4.3	0.065
									Methereological information D2.4.4	D2.4.4	0.044
									Energy consumption D2.4.5	D2.4.5	0.069
									Energy storage D2.4.6	D2.4.6	0.069
									Energy use D2.4.7	D2.4.7	0.066
									Water consumption D2.4.8	D2.4.8	0.067
									Gas Consumption D2.4.9	D2.4.9	0.065
									Anomaly of system D2.4.10	D2.4.10	0.069
									Smoke detectors D2.4.11	D2.4.11	0.072

Plants D3	D3	3.12	Water management D3.1	D3.1	0.22	Water reuse D3.1.1	D3.1.1	0.078
						Water storage D3.1.2	D3.1.2	0.079
						Water dispertion D3.1.3	D3.1.3	0.063
			Shieldings D3.2	D3.2	0.24			
			Photovoltaic system D3.3	D3.3	0.24			
			Heating and cooling D3.4	D3.4	0.24			
			Gas system D3.5	D3.5	0.16			
			Electrical system D3.6	D3.6	0.19			
			Ventilation system D3.7	D3.7	0.22			
			Fire-fighting system D3.8	D3.8	0.21	Sprinkler D3.8.1	3.8.1	0.033
						Compartmentalization D3.8.2	3.8.2	0.038
						Fire resistant wall D3.8.3	3.8.3	0.040
						Fire-fighting spray D3.8.4	3.8.4	0.024
						Fire escape stairs D3.8.5	3.8.5	0.038
						Escape routes and fire-fighting doors D3.8.6	3.8.6	0.037
			Waste treatment plant D3.9	D3.9	0.21			
			Exhaust system D3.10	D3.10	0.19			
			Lightning protection system D3.11	D3.11	0.16			
			Energy supply system D3.12	D3.12	0.22			
			Earthing system D3.13	D3.13	0.19			
			Wind power plant D3.14	D3.14	0.19			
			Geothermal plant D3.15	D3.15	0.22			
Envelope D4	D4	3.03	Facade D4.1	D4.1	0.44	Double-skin façade D4.1.1	D4.1.1	0.112
						Lodge D4.1.2	D4.1.2	0.029
						Bow windows D4.1.3	D4.1.3	0.020
						Panels D4.1.4	D4.1.4	0.073
						Glazed façade D4.1.5	D4.1.5	0.059
						Dynamic façade D4.1.6	D4.1.6	0.044
						Single-skin façade D4.1.7	D4.1.7	0.020
						Green façade D4.1.8	D4.1.8	0.083
			Windows D4.2	D4.2	0.38	Photochromic glass D4.2.1	D4.2.1	0.012
						Electrochromic glass D4.2.2	D4.2.2	0.009
						Thermochromic glass D4.2.3	D4.2.3	0.034
						Collector glass D4.2.4	D4.2.4	0.019
						Tempered or coloured glass D4.2.5	D4.2.5	0.022
						Low-emissive glass D4.2.6	D4.2.6	0.087
						Reflective glass D4.2.7	D4.2.7	0.022
						Spectrally selective glazing D4.2.8	D4.2.8	0.034
						Double-glazing D4.2.9	D4.2.9	0.075
						Laminated glass D4.2.10	D4.2.10	0.065
			Shadings D4.3	D4.3	0.44	Horizontal brise soleil D4.3.1	D4.3.1	0.065
						Vertical brise soleil D4.3.2	D4.3.2	0.059
						Rolling shutter D4.3.3	D4.3.3	0.048
						Curtain D4.3.4	D4.3.4	0.039
						Venetian blind D4.3.5	D4.3.5	0.030
						External shutter D4.3.6	D4.3.6	0.036
						Grating D4.3.7	D4.3.7	0.009
						Green panels D4.3.8	D4.3.8	0.015
						Expanded or microperforated metal D4.3.9	D4.3.9	0.027
						Window with integrated sun screens D4.3.10	D4.3.10	0.051
						Offsets or Indentations D4.3.11	D4.3.11	0.062
			Thermal insulation D4.4	D4.4	0.44			
			Acoustic insulation D4.5	D4.5	0.41			
			Natural ventilation D4.6	D4.6	0.46			
			Natural lighting D4.7	D4.7	0.45			

			Structure D5	D5	2.96	Walls D5.1	D5.1	0.55	Wall with insulation D5.1.1	D5.1.1	0.134
									TROMBE wall D5.1.2	D5.1.2	0.031
									Ventilated façade D5.1.3	D5.1.3	0.118
									Energy façade D5.1.4	D5.1.4	0.072
									Bioclimatic façade D5.1.5	D5.1.5	0.087
									Structural glass façade D5.1.6	D5.1.6	0.036
									Wall with internal insulation D5.1.7	D5.1.7	0.041
									Wall with double insulation D5.1.8	D5.1.8	0.031
						Floors D5.2	D5.2	0.43	Radiant floor D5.2.1	D5.2.1	0.112
									Prefabricated slab D5.2.2	D5.2.2	0.056
									False sealing for installations D5.2.3	D5.2.3	0.156
									Thermo-acoustically insulated floor D5.2.4	D5.2.4	0.106
						Foundations D5.3	D5.3	0.35	Platea foundation D5.3.1	D5.3.1	0.040
									Inverted T-beams foundation D5.3.2	D5.3.2	0.030
									Igloo foundation D5.3.3	D5.3.3	0.110
									Earthquake resistant foundation D5.3.4	D5.3.4	0.070
									Seismic joints and energy dissipators D5.3.5	D5.3.5	0.100
						Vertical connectors D5.4	D5.4	0.47	Escalators D5.4.1	D5.4.1	0.058
									Stairs D5.4.2	D5.4.2	0.058
									Moving walkways D5.4.3	D5.4.3	0.008
									Hydraulic lift D5.4.4	D5.4.4	0.071
									Electric lift D5.4.5	D5.4.5	0.062
									Panoramic lift D5.4.6	D5.4.6	0.071
									Freight elevator D5.4.7	D5.4.7	0.037
									Fire escape stairs D5.4.8	D5.4.8	0.083
									Fireproof doors D5.4.9	D5.4.9	0.092
									Catwalks D5.4.10	D5.4.10	0.046
						Roof D5.5	D5.5	0.59	Ventilated roof D5.5.1	D5.5.1	0.130
									Warm roof D5.5.2	D5.5.2	0.050
									Cold roof D5.5.3	D5.5.3	0.014
									Green roof D5.5.4	D5.5.4	0.165
									Sandwich roof D5.5.5	D5.5.5	0.036
									Photovoltaic roof D5.5.6	D5.5.6	0.194
						Interior design D5.6	D5.6	0.58	Open spaces D5.6.1	D5.6.1	0.189
									Movable panels D5.6.2	D5.6.2	0.203
									Double height spaces D5.6.3	D5.6.3	0.098
									Spaces for collectivity on multiple levels D5.6.4	D5.6.4	0.091

Category	Code	Weight (%)	Attributes	Code	Weight (%)	Sub-attributes 1	Code	Weight (%)	Sub-attributes 2	Code	Weight (%)
SOCIAL DESIGN CRITERIA E	E	15.26	Stakeholders E1	E1	5.15	Management and control E1.1	E1.1	0.73	Program manager E1.1.1	E1.1.1	0.104
									Management engineer E1.1.2	E1.1.2	0.086
									Project manager E1.1.3	E1.1.3	0.122
									Facility manager E1.1.4	E1.1.4	0.113
									Site manager E1.1.5	E1.1.5	0.109
									BIM manager E1.1.6	E1.1.6	0.108
									Consultants and accountants E1.1.7	E1.1.7	0.087
						Project and construction E1.2	E1.2	1.02	Inventors E1.2.1	E1.2.1	0.038
									Architects E1.2.2	E1.2.2	0.051
									Designer E1.2.3	E1.2.3	0.055
									Developers E1.2.4	E1.2.4	0.053
									Graphic designers E1.2.5	E1.2.5	0.039
									Construction team E1.2.6	E1.2.6	0.056
									Workers E1.2.7	E1.2.7	0.044
									IT engineers E1.2.8	E1.2.8	0.027
									Structural Engineers E1.2.9	E1.2.9	0.054
									Electrical Engineers E1.2.10	E1.2.10	0.044
									Environmental Engineers E1.2.11	E1.2.11	0.048
									Technicians E1.2.12	E1.2.12	0.046
									Building engineers E1.2.13	E1.2.13	0.053
									Geologists E1.2.14	E1.2.14	0.042
									Chemical engineers E1.2.15	E1.2.15	0.027
									Civil engineers E1.2.16	E1.2.16	0.045
									Sociologists E1.2.17	E1.2.17	0.034
									Archaeologists E1.2.18	E1.2.18	0.029
									Academic experts E1.2.19	E1.2.19	0.026
									Surveyors E1.2.20	E1.2.20	0.032
									Urbanists E1.2.21	E1.2.21	0.050
									Sub-contractors E1.2.22	E1.2.22	0.037
									Landscapers E1.2.23	E1.2.23	0.044
									Pollution manager E1.2.24	E1.2.24	0.047
						Burocracy and laws E1.3	E1.3	0.7	Lawyers E1.3.1	E1.3.1	0.075
									Regulators E1.3.2	E1.3.2	0.080
									Policy makers E1.3.3	E1.3.3	0.088
									Judges E1.3.4	E1.3.4	0.061
									Public administrations E1.3.5	E1.3.5	0.112
									Municipal Council E1.3.6	E1.3.6	0.109
									Regional Council E1.3.7	E1.3.7	0.101
									Government E1.3.8	E1.3.8	0.074
						Site history and preservation E1.4	E1.4	0.86	Architectural historians E1.4.1	E1.4.1	0.150
									Professors E1.4.2	E1.4.2	0.134
									Cultural association for building preservation E1.4.3	E1.4.3	0.201
									International Council on Monuments and Sites E1.4.4	E1.4.4	0.194
									Heritage consultant E1.4.5	E1.4.5	0.181
						Selling E1.5	E1.5	0.91	Broker E1.5.1	E1.5.1	0.092
									Marketeers E1.5.2	E1.5.2	0.123
									Sales company E1.5.3	E1.5.3	0.156
									Owners E1.5.4	E1.5.4	0.202
									Promoters E1.5.5	E1.5.5	0.171
									Sponsors and investors E1.5.6	E1.5.6	0.165
						Users E1.6	E1.6	0.95	Community E1.6.1	E1.6.1	0.195
									Private and public associations E1.6.2	E1.6.2	0.169
									Neighbors E1.6.3	E1.6.3	0.179
									Tourists E1.6.4	E1.6.4	0.153
									ONG E1.6.5	E1.6.5	0.122
									Employees, students and workers E1.6.6	E1.6.6	0.132

Community sense of place E2	E2	5	Building image E2.1	E2.1	0.5	High	E2.1.1	0.166
						Medium	E2.1.2	0.334
						Low	E2.1.3	0.500
			Neighbourhood perception E2.2	E2.2	0.49	High	E2.2.1	0.163
						Medium	E2.2.2	0.327
						Low	E2.2.3	0.490
			Aesthetic identity E2.3	E2.3	0.44	High	E2.3.1	0.147
						Medium	E2.3.2	0.293
						Low	E2.3.3	0.440
			Building social utility E2.4	E2.4	0.48	High	E2.4.1	0.160
						Medium	E2.4.2	0.320
						Low	E2.4.3	0.480
			Relationship Building-Environment E2.5	E2.5	0.45	High	E2.5.1	0.150
						Medium	E2.5.2	0.300
						Low	E2.5.3	0.450
			Usability E2.6	E2.6	0.47	High	E2.6.1	0.157
						Medium	E2.6.2	0.313
						Low	E2.6.3	0.470
			Building legibility E2.7	E2.7	0.34	High	E2.7.1	0.113
						Medium	E2.7.2	0.227
						Low	E2.7.3	0.340
			Spaces liveability E2.8	E2.8	0.48	High	E2.8.1	0.160
						Medium	E2.8.2	0.320
						Low	E2.8.3	0.480
			Building attractiveness E2.9	E2.9	0.48	High	E2.9.1	0.160
						Medium	E2.9.2	0.320
						Low	E2.9.3	0.480
			Social inclusion E2.10	E2.10	0.46	High	E2.10.1	0.153
						Medium	E2.10.2	0.307
						Low	E2.10.3	0.460
			Social active participation in planning procedures E2.11	E2.11	0.42	High	E2.11.1	0.140
						Medium	E2.11.2	0.280
						Low	E2.11.3	0.420
Social monitoring E3	E3	5.11	Analysis of society needs E3.1	E3.1	2.49	Increase of public spaces E3.1.1	E3.1.1	0.309
						Increase of services E3.1.2	E3.1.2	0.391
						Increase of green spaces E3.1.3	E3.1.3	0.374
						Increase public transports E3.1.4	E3.1.4	0.277
						Improvement of urban infrastructures E3.1.5	E3.1.5	0.228
						New job opportunities E3.1.6	E3.1.6	0.325
						Increase district security and safety E3.1.7	E3.1.7	0.293
						Spaces accessibility E3.1.8	E3.1.8	0.293
			Community analysis E3.2	E3.2	2.62	Analysis of population age E3.2.1	E3.2.1	0.642
						Population density E3.2.2	E3.2.2	0.374
						Level of education E3.2.3	E3.2.3	0.321
						District lifestyle E3.2.4	E3.2.4	0.668
						Social inclusion E3.2.5	E3.2.5	0.241
						Crime E3.2.6	E3.2.6	0.374

Category	Code	Weight (%)	Attributes	Code	Weight (%)	Sub-attributes 1	Code	Weight (%)	Sub-attributes 2	Code	Weight (%)	Activities	Code	Weight (%)
			Times F1	F1	2.38	Building site availability F1.1	F1.1	0.12						
						Building expropriation F1.2	F1.2	0.14						
						Building site analysis and monitoring F1.3	F1.3	0.12						
						Masterplan idea F1.4	F1.4	0.11						
						Plan development and approval F1.5	F1.5	0.14	Preliminary draft approval F1.5.1	F1.5.1	0.044			
									Final draft approval F1.5.2	F1.5.2	0.046			
									Executive plan development and approval F1.5.3	F1.5.3	0.050			
						Area delimitation F1.6	F1.6	0.07						
						Building construction F1.7	F1.7	0.11	Site layout F1.7.1	F1.7.1	0.007			
									Arrangement of provisional works F1.7.2	F1.7.2	0.006			
									Ground leveling F1.7.3	F1.7.3	0.005			
									Foundation digging F1.7.4	F1.7.4	0.006			
									Foundations F1.7.5	F1.7.5	0.007			
									Structure (pillars and beams) F1.7.6	F1.7.6	0.008			
									Plants installation F1.7.7	F1.7.7	0.007			
									Façade F1.7.8	F1.7.8	0.007			
									Roof F1.7.9	F1.7.9	0.007			
									Facade technologies F1.7.10	F1.7.10	0.007			
									Interior design F1.7.11	F1.7.11	0.003			
									Walls F1.7.12	F1.7.12	0.005			
									Vertical connectors F1.7.13	F1.7.13	0.007			
									Floors F1.7.14	F1.7.14	0.007			
									Finishes F1.7.15	F1.7.15	0.005			
									Implemetation of domotic systems F1.7.16	F1.7.16	0.005			
									Implementation of security technological systems F1.7.17	F1.7.17	0.005			
									Realization of restrooms F1.7.18	F1.7.18	0.006			
						Energy performances certifications F1.8	F1.8	0.11						
						Maintenance activities F1.9	F1.9	0.11	Ordinary maintenance F1.9.1	F1.9.1	0.025			
									Exstraordinary maintenance F1.9.2	F1.9.2	0.031			
									External areas maintenance F1.9.3	F1.9.3	0.025			
									Infrastructures maintanance F1.9.4	F1.9.4	0.030			
						Reclamation works F1.10	F1.10	0.14						
						Surveys and measurements F1.11	F1.11	0.09						
						External area construction F1.12	F1.12	0.1	Ground leveling F1.12.1	F1.12.1	0.017			
									Flooring F1.12.2	F1.12.2	0.014			
									Insertion of urban furnitures and parking areas F1.12.3	F1.12.3	0.015			
									Insertion of vegetation and green spaces F1.12.4	F1.12.4	0.018			
									Insertion of urban lightning F1.12.5	F1.12.5	0.017			
									Construction of waste disposal area F1.12.6	F1.12.6	0.019			
						Building recovery project acceptance F1.13	F1.13	0.13						
						Testing F1.14	F1.14	0.11						
									Consolidation of stone structures F1.15.1	F1.15.1	0.017	Consolidation of foundations F1.15.1.1	F1.15.1.1	0.0043
												Consolidation of walls F1.15.1.2	F1.15.1.2	0.0012
												Consolidation of archs and vaults F1.15.1.3	F1.15.1.3	0.0034
												Consolidation of pillars F1.15.1.4	F1.15.1.4	0.0014
												Consolidation and preservation of historical floors F1.15.1.5	F1.15.1.5	0.0030
												Consolidation of vertical connectors F1.15.1.6	F1.15.1.6	0.0019
												Reconstruction of degraded parts F1.15.1.7	F1.15.1.7	0.0018

Criterion	Code	Weight	Sub-criterion	Code	Weight	Indicator	Code	Weight	Sub-indicator	Code	Weight	Level	Code	Weight
LEGAL DESIGN CRITERIA F	F	12.86				Building recovery procedures F1.15	F1.15	0.14	Consolidation of reinforced concrete and mixed structures F1.15.2	F1.15.2	0.017	Consolidation of foundations F1.15.2.1	F1.15.2.1	0.0041
												Cortical recovery of reinforced concrete elements F1.15.2.2	F1.15.2.2	0.0010
												Consolidation of pillars F1.15.2.3	F1.15.2.3	0.0027
												Consolidation of beams F1.15.2.4	F1.15.2.4	0.0027
												Consolidation of floors and roof F1.15.2.5	F1.15.2.5	0.0024
												Consolidation of walls F1.15.2.6	F1.15.2.6	0.0010
												Consolidation of vertical connectors F1.15.2.7	F1.15.2.7	0.0022
												Reconstruction of degraded parts F1.15.2.8	F1.15.2.8	0.0009
									Dampness reduction F1.15.3	F1.15.3	0.016			
									Consolidation of wooden structures F1.15.4	F1.15.4	0.017			
									Consolidation of steel structures F1.15.5	F1.15.5	0.016			
									Insertion of openings F1.15.6	F1.15.6	0.014			
									Provisional works F1.15.7	F1.15.7	0.012			
									Seismic adaptation interventions F1.15.8	F1.15.8	0.019			
									Material recovery and protection actions F1.15.9	F1.15.9	0.013			
									Restoration of existing toilets F1.15.10	F1.15.10	0.009			
									Restoration of existing plants F1.15.11	F1.15.11	0.016			
						Materials extraction F1.16	F1.16	0.08						
						Components production F1.17	F1.17	0.1						
						Transport F1.18	F1.18	0.08						
						Building disassembly F1.19	F1.19	0.1						
						Waste disposal F1.20	F1.20	0.09						
						Building demolition F1.21	F1.21	0.12						
						Activities planning F1.22	F1.22	0.09						
			Quality, safety and security F2	F2	2.71	Building security F2.1	F2.1	0.38	High level of security	F2.1.1	0.13			
									Medium level of security	F2.1.2	0.25			
									Low level of security	F2.1.3	0.38			
						Building architectural quality F2.2	F2.2	0.36	Structure F2.2.1	F2.2.1	0.061	High quality	F2.2.1.1	0.02
												Medium quality	F2.2.1.2	0.041
												Low quality	F2.2.1.3	0.061
									Cover/envelope F2.2.2	F2.2.2	0.052	High quality	F2.2.2.1	0.017
												Medium quality	F2.2.2.2	0.035
												Low quality	F2.2.2.3	0.052
									Connectors F2.2.3	F2.2.3	0.056	High quality	F2.2.3.1	0.019
												Medium quality	F2.2.3.2	0.037
												Low quality	F2.2.3.3	0.056
									Materials F2.2.4	F2.2.4	0.053	High quality	F2.2.4.1	0.018
												Medium quality	F2.2.4.2	0.035
												Low quality	F2.2.4.3	0.053
									Plants F2.2.5	F2.2.5	0.046	High quality	F2.2.5.1	0.015
												Medium quality	F2.2.5.2	0.031
												Low quality	F2.2.5.3	0.046
									Technologies F2.2.6	F2.2.6	0.044	High quality	F2.2.6.1	0.015
												Medium quality	F2.2.6.2	0.029
												Low quality	F2.2.6.3	0.044
									Site F2.2.7	F2.2.7	0.048	High quality	F2.2.7.1	0.016
												Medium quality	F2.2.7.2	0.032
												Low quality	F2.2.7.3	0.048
						Comfort indoor F2.3	F2.3	0.36	High level of comfort	F2.3.1	0.12			
									Medium level of comfort	F2.3.2	0.24			
									Low level of comfort	F2.3.3	0.36			
						Users safety F2.4	F2.4	0.38	High safety	F2.4.1	0.13			
									Medium safety	F2.4.2	0.25			
									Low safety	F2.4.3	0.38			

			Passive surveillance F2.5	F2.5	0.28	High	F2.5.1	0.09
						Medium	F2.5.2	0.19
						Low	F2.5.3	0.28
			Green spaces quality F2.6	F2.6	0.28	High quality	F2.6.1	0.09
						Medium quality	F2.6.2	0.19
						Low quality	F2.6.3	0.28
			Occupational health and security F2.7	F2.7	0.32	High level of secutity	F2.7.1	0.11
						Medium level of secutity	F2.7.2	0.21
						Low level of secutity	F2.7.3	0.32
			Quality of natural areas F2.8	F2.8	0.34	High quality	F2.8.1	0.11
						Medium quality	F2.8.2	0.23
						Low quality	F2.8.3	0.34
Fire protection and disability access F3	F3	2.56	Accessibility F3.1	F3.1	1.28	High	F3.1.1	0.43
						Medium	F3.1.2	0.85
						Low	F3.1.3	1.28
			Fire protection F3.2	F3.2	1.28	High	F3.2.1	0.43
						Medium	F3.2.2	0.85
						Low	F3.2.3	1.28
Respect of standards F4	F4	2.45	Building distance F4.1	F4.1	0.175			
			H max F4.2	F4.2	0.175			
			Air-illuminating conditions F4.3	F4.3	0.175			
			Relationship surface/number of people F4.4	F4.4	0.175			
			Volumes addition F4.5	F4.5	0.175			
			Surfaces of spaces F4.6	F4.6	0.175			
			Building density F4.7	F4.7	0.175			
			Relationship building area/green spaces F4.8	F4.8	0.175			
			Surfaces of public spaces F4.9	F4.9	0.175			
			Number of escape routes F4.10	F4.10	0.175			
			Landscape constraint F4.11	F4.11	0.175			
			Urban constraint F4.12	F4.12	0.175	Road respect band F4.12.1	F4.12.1	0.035
						Cemetery respect band F4.12.2	F4.12.2	0.035
						Railway respect band F4.12.3	F4.12.3	0.035
						Airport respect band F4.12.4	F4.12.4	0.035
						Power line respect band F4.12.5	F4.12.5	0.035
			Seismic constraint F4.13	F4.13	0.175			
			Hydrogeological constraint F4.14	F4.14	0.175			
Intervention feasibility check F5	F5	2.76	Analysis of the new construction intervention F5.1	F5.1	0.46			
			Analysis of the building renovation intervention F5.2	F5.2	0.46			
			Legal-regulatory feasibility check F5.3	F5.3	0.46			
			Technical-operational feasibility check F5.4	F5.4	0.46			
			Economic-financial feasibility check F5.5	F5.5	0.46			
			Management-maintenance feasibility check F5.6	F5.6	0.46			

Category	Code	Weight (%)	Attributes	Code	Weight (%)	Sub-attributes 1	Code	Weight (%)	Sub-attributes 2	Code	Weight (%)
POLITICAL DESIGN CRITERIA G	G	10.4	Zoning G1	G1	2.6	Urban masterplan composition G1.1	G1.1	0.53			
						Site location G1.2	G1.2	0.62			
						City neighbourhood characteristics G1.3	G1.3	0.53			
						Distance from the city center G1.4	G1.4	0.42			
						Functional zoning classification and typologyG1.5	G1.5	0.50			
			Decrees and laws G2	G2	2.8	Safety laws during works G2.1	G2.1	0.09			
						Fire prevention laws G2.2	G2.2	0.13			
						Technical standards and price lists G2.3	G2.3	0.16			
						Town planning regulations and laws G2.4	G2.4	0.15			
						Municipal plans G2.5	G2.5	0.14	Land-use plan G2.5.1	G2.5.1	0.012
									Reclamation plan G2.5.2	G2.5.2	0.005
									Territorial Landscape Plan G2.5.3	G2.5.3	0.028
									Multi-year implementation programmes G2.5.4	G2.5.4	0.013
									Detailed development plans G2.5.5	G2.5.5	0.009
									Plans for productive settlements G2.5.6	G2.5.6	0.011
									Recovery and restorage plans G2.5.7	G2.5.7	0.022
									Programmes for urban regeneration G2.5.8	G2.5.8	0.020
									Municipal building code G2.5.9	G2.5.9	0.021
						Regional plans G2.6	G2.6	0.13	Territorial and coordination plan G2.6.1	G2.6.1	0.026
									Thematic Territorial Urban Plan G2.6.2	G2.6.2	0.021
									Hydrogeological plan G2.6.3	G2.6.3	0.040
									Regional Territorial Landscape Plan G2.6.4	G2.6.4	0.016
									Regional building code G2.6.5	G2.6.5	0.026
						National plans G2.7	G2.7	0.13	Consolidated Act on construction G2.7.1	G2.7.1	0.043
									Procurement and public contracts code G2.7.2	G2.7.2	0.038
									New Cultural Heritage Code G2.7.3	G2.7.3	0.049
						Eurocode G2.8	G2.8	0.14			
						Building monitoring procedures G2.9	G2.9	0.11			
						Environment protection acts G2.10	G2.10	0.15			
						Recovery and restoration laws G2.11	G2.11	0.15			
						Energy certifications G2.12	G2.12	0.15	CasaKlima G2.12.1	G2.12.1	0.018
									LEED G2.12.2	G2.12.2	0.026
									ITACA Protocol G2.12.3	G2.12.3	0.024
									Nzeb G2.12.4	G2.12.4	0.022
									Green Star G2.12.5	G2.12.5	0.007
									CASBEE G2.12.6	G2.12.6	0.009
									Energy performance certificate G2.12.7	G2.12.7	0.022
									Passivhaus G2.12.8	G2.12.8	0.014
									BREEAM G2.12.9	G2.12.9	0.008
						Expropriation laws G2.13	G2.13	0.12			
						Disabilities act issues G2.14	G2.14	0.15			
						User safety and security laws G2.15	G2.15	0.13			
						UNI standards G2.16	G2.16	0.13			
						Management plans G2.17	G2.17	0.12			
						Building construction and preservation regulations and standards G2.18	G2.18	0.13			
						Maintenance plans G2.19	G2.19	0.13			
						Declaration of activity beginning G2.20	G2.20	0.12			
						Building licence G2.21	G2.21	0.13			
			Community support and ownership G3	G3	2.39	High influence G3.1	G3.1	0.80			
						Medium influence G3.2	G3.2	1.59			
						Low influence G3.3	G3.3	2.39			
			Building resilience G4	G4	2.61	High building resilience G4.1	G4.1	0.87			
						Medium building resilience G4.2	G4.2	1.74			
						Low building resilience G4.3	G4.3	2.61			

Category	Code	Weight (%)	Attributes	Code	Weight (%)	Sub-attributes	Code	Weight (%)
Risks	H	100.00	Existing building	H1	33.27	Presence of asbestos	H1.1	5.13
						Collapses	H1.2	4.78
						Vandalism	H1.3	2.95
						Inflexible layout	H1.4	3.76
						Building defections	H1.5	3.85
						Spatial constraints	H1.6	3.98
						Building vulnerability	H1.7	4.34
						Building incompatibility with context	H1.8	4.48
			Site	H2	16.12	Inadequate services for population	H2.1	4.00
						Hazards	H2.2	4.63
						Poor amenities	H2.3	3.83
						Noise	H2.4	3.66
			During and after building conversion processes	H3	50.61	Increasing of project and construction times	H3.1	4.22
						Increasing of bureaucratic times	H3.2	4.71
						No respect of rules and corruption	H3.3	4.87
						Construction errors	H3.4	4.95
						Technical constraints	H3.5	4.38
						Increasing of construction costs	H3.6	4.63
						Building disuse by users	H3.7	4.54
						Lack of investments and disorganisation between stakeholders	H3.8	4.96
						Incompatibility of the project with current regulations	H3.9	4.70
						Accidents at work	H3.10	4.15
						Incompatibility of the expected functions towards the actual population needs	H3.11	4.50

ANNEX C-a

(DCS main categories, attributes, sub-attributes 1, sub-attributes 2 and activities division in the building recovery table)

1. Evaluation ex-ante and site monitoring and survey										2. Programming activities for building recovery and transformation					3. Master plan conception (project of external areas and landmarks)					4. Design of the adaptive reuse intervention (hypothesis of building refurbishment and conversion actions)									
A	A1	A3	A4	A5	A6					A2	A7	A8			A2.14	A2.15				A2.1	A2.2	A2.3	A2.4	A2.5	A2.6	A2.7	A2.8	A2.9	A2.10
A1.1	A1.2	A1.3	A1.4	A1.5	A1.6	A1.7	A1.8	A1.9	A1.10	A1.11.11										A2.11	A2.12	A2.13	A2.19						
A1.11															C4					A2.2.1	A2.2.2	A2.3.1	A2.3.2	A2.4.1	A2.4.2	A2.5.1	A2.5.2	A2.6.1	A2.6.2
A3.1	A3.2	A3.3	A3.4	A3.5	A3.6					B	B1	B3			C1.1	C1.4	C1.5	C2.2		A2.10.1	A2.10.2	A2.11.1	A2.11.2	A2.11.3					
A4.1	A4.2	A4.3	A4.4	A4.5	A4.6	A4.7	A4.8	A4.9	A4.10	B3.1	B3.2				C4.6	C4.8	C4.9	C4.11											
A4.11															C1.5.1	C1.5.2	C1.5.3	C1.5.4	C1.5.5	B1.6	B1.8								
A5.1	A5.2	A5.3	A5.4	A5.5						C1					C4.6.1	C4.6.2	C4.6.4	C4.6.5	C4.6.7	B1.6.1	B1.6.2	B1.6.3	B1.6.4	B1.6.5	B1.6.6	B1.6.7	B1.6.8	B1.6.9	B1.6.10
A6.1	A6.2	A6.3	A6.4	A6.5	A6.6	A6.7	A6.8								C4.8.4	C4.8.5	C4.8.6			B8.1.1	B8.1.2	B8.1.3	B8.1.4	B8.1.5	B8.1.6	B8.1.7			
A1.3.1	A1.3.2	A1.3.3	A1.3.4	A1.3.5	A1.3.6	A1.3.7	A1.3.8			D	D1	D3	D4	D5	C4.9.1	C4.9.2	C4.9.3	C4.9.4	C4.9.7										
A1.4.1	A1.4.2	A1.4.3	A1.4.4	A1.4.5	A1.4.6	A1.4.7	A1.4.8	A1.4.9	A1.4.10						C4.9.8					C1.2	C1.3	C1.4	C2.1						
A1.5.1	A1.5.2	A1.5.3	A1.5.4	A1.5.5	A1.5.6	A1.5.7	A1.5.8	A1.5.9	A1.5.10	E1.1.1	E1.1.2	E1.1.3	E1.1.7		C4.11.1	C4.11.2	C4.11.3			C4.1	C4.2	C4.3	C4.4	C4.5	C4.6	C4.7	C4.8	C4.9	C4.10
A1.5.11	A1.6.1	A1.6.2	A1.6.3	A1.6.4						E1.2.2	E1.2.8	E1.2.9	E1.2.11	E1.2.13						C4.11									
A1.7.1	A1.7.2	A1.7.3	A1.7.4	A1.7.5	A1.7.6	A1.8.1	A1.8.2	A1.8.3	A1.8.4	E1.2.16	E1.2.20	E1.2.21	E1.2.23		E2.11					C4.1.1	C4.1.2	C4.1.3	C4.1.4	C4.1.5	C4.1.6	C4.1.7	C4.1.8	C4.1.9	C4.1.10
A1.9.1	A1.9.2	A1.10.1	A1.10.2	A1.10.3											E1.1.1	E1.1.2	E1.1.3	E1.1.5	E1.1.6	C4.1.11	C4.1.12	C4.1.13	C4.1.14	C4.1.15					
A1.11.1	A1.11.2	A1.11.3	A1.11.4	A1.11.5	A1.11.6	A1.11.7	A1.11.8	A1.11.9	A1.11.10	F5					E1.2.1	E1.2.2	E1.2.3	E1.2.5	E1.2.8	C4.2.1	C4.2.2	C4.2.3	C4.2.4	C4.2.5	C4.2.6	C4.2.7	C4.2.8	C4.2.9	C4.2.10
A1.11.11	A1.11.12	A1.11.13	A1.11.14	A1.11.15						F1.10	F1.22				E1.2.10	E1.2.11	E1.2.13	E1.2.14	E1.2.18	C4.3.1	C4.3.2	C4.3.3	C4.3.4						
A3.1.1	A3.1.2	A3.1.3	A3.1.4	A3.1.5	A3.1.6					F5.1	F5.2	F5.3	F5.4	F5.5	E1.2.19	E1.2.20	E1.2.21	E1.2.23		C4.4.1	C4.4.2	C4.4.3	C4.4.4	C4.4.5	C4.4.6	C4.4.7	C4.4.8	C4.4.9	C4.4.10
A3.2.1	A3.2.2	A3.2.3	A3.2.4	A3.2.5						F5.6					E1.4.2					C4.4.11	C4.4.12	C4.4.13	C4.4.14	C4.4.15					
A3.4.1	A3.4.2	A3.4.3	A3.4.4	A3.4.5	A3.4.6	A3.4.7	A3.4.8	A3.4.9												C4.5.1	C4.5.2	C4.5.3	C4.5.4	C4.5.5	C4.5.6	C4.5.7	C4.5.8	C4.5.9	C4.5.10
A3.5.1	A3.5.2	A3.5.3	A3.5.4							G3					F4					C4.5.11	C4.5.12	C4.5.13	C4.5.14	C4.5.15	C4.5.16	C4.5.17	C4.5.18	C4.5.19	
A3.6.1	A3.6.2	A3.6.3	A3.6.4	A3.6.5	A3.6.6	A3.6.7	A3.6.8	A3.6.9	A3.6.10	G2.4	G2.10	G2.11			F1.4					C4.6.1	C4.6.2	C4.6.3	C4.6.4	C4.6.5	C4.6.6	C4.6.7			
															F4.11	F4.12	F4.13	F4.14		C4.7.1	C4.7.2	C4.7.3	C4.7.4	C4.7.5	C4.7.6	C4.7.7	C4.7.8	C4.7.9	C4.7.10
C	C2									H3	H3.8				F4.12.1	F4.12.2	F4.12.3	F4.12.4	F4.12.5	C4.7.11	C4.7.12	C4.7.13	C4.7.14	C4.7.15	C4.7.16	C4.7.17	C4.7.18	C4.7.19	
																				C4.8.1	C4.8.2	C4.8.3	C4.8.4	C4.8.5	C4.8.6	C4.8.7			
E	E1	E2	E3												G2.3	G2.5	G2.6	G2.15	G2.16	C4.9.3	C4.9.4	C4.9.5	C4.9.6	C4.9.8					
E1.1	E1.2	E1.4													G2.5.1	G2.5.2	G2.5.3	G2.5.4	G2.5.5	C4.10.1	C4.10.2	C4.10.3	C4.10.4	C4.10.5	C4.10.6	C4.10.7	C4.10.8	C4.10.9	C4.10.10
E2.1	E2.2	E2.5	E2.7	E2.11											G2.5.6	G2.5.7	G2.5.8	G2.5.9		C4.10.11									
E3.1	E3.2														G2.6.1	G2.6.2	G2.6.3	G2.6.4	G2.6.5	C4.11.1	C4.11.2	C4.11.3							
E1.1.1	E1.1.2	E1.1.3	E1.1.5																										
E1.2.2	E1.2.3	E1.2.9	E1.2.11	E1.2.13	E1.2.14	E1.2.15	E1.2.16	E1.2.17	E1.2.18						H3.8														
E1.2.19	E1.2.20	E1.2.21	E1.2.23	E1.2.24																									
E1.4.1	E1.4.2	E1.4.3	E1.4.4	E1.4.5																									
E3.1.1	E3.1.2	E3.1.3	E3.1.4	E3.1.5	E3.1.6	E3.1.7	E3.1.8																						
E3.2.1	E3.2.2	E3.2.3	E3.2.4	E3.2.5	E3.2.6																								
F	F1																												
F1.3	F1.11																												
G	G1	G2	G4																										
G1.1	G1.2	G1.3	G1.4	G1.5																									
G2.4	G2.5	G2.6	G2.7	G2.8	G2.9	G2.18																							
G2.5.1	G2.5.2	G2.5.3	G2.5.4	G2.5.5	G2.5.6	G2.5.7	G2.5.8	G2.5.9																					
G2.6.1	G2.6.2	G2.6.3	G2.6.4	G2.6.5																									
G2.7.1	G2.7.2	G2.7.3																											
H	H1	H2																											
H1.1	H1.2	H1.3	H1.4	H1.5	H1.6	H1.7	H1.8																						
H2.1	H2.2	H2.3	H2.4																										

4. Design of the adaptive reuse intervention (hypothesis of building refurbishment and conversion actions)									
D2									
D1.1	D1.2	D1.3	D1.4	D1.5	D1.6	D1.7	D1.8	D1.9	D1.10
D3.1	D3.2	D3.3	D3.4	D3.5	D3.6	D3.7	D3.8	D3.9	D3.10
D3.11	D3.12	D3.13	D3.14	D3.15					
D4.1	D4.2	D4.3	D4.4	D4.5	D4.6	D4.7			
D5.1	D5.2	D5.3	D5.4	D5.5	D5.6				
D1.1.1	D1.1.2	D1.1.3	D1.1.4	D1.1.5	D1.1.6	D1.1.7	D1.1.8	D1.1.9	D1.1.10
D1.1.11	D1.1.12	D1.1.13	D1.1.14	D1.1.15	D1.1.16	D1.1.17	D1.1.18	D1.1.19	D1.1.20
D1.1.21	D1.1.22	D1.1.23							
D1.2.1	D1.2.2	D1.2.3	D1.2.4						
D1.3.1	D1.3.2	D1.3.3	D1.3.4	D1.3.5	D1.3.6	D1.3.7	D1.3.8	D1.3.9	D1.3.10
D1.3.11	D1.3.12	D1.3.13	D1.3.14	D1.3.15	D1.3.16	D1.3.17			
D1.4.1	D1.4.2	D1.4.3	D1.4.4	D1.4.5					
D1.5.1	D1.5.2	D1.5.3	D1.5.4	D1.5.5	D1.5.6	D1.5.7			
D1.6.1	D1.6.2	D1.6.3	D1.6.4	D1.6.5	D1.6.6	D1.6.7			
D1.7.1	D1.7.2	D1.7.3	D1.7.4	D1.7.5	D1.7.6	D1.7.7	D1.7.8		
D1.8.1	D1.8.2	D1.8.3	D1.8.4	D1.8.5	D1.8.6	D1.8.7	D1.8.8	D1.8.9	D1.8.10
D1.8.11									
D1.9.1	D1.9.2	D1.9.3							
D1.10.1	D1.10.2	D1.10.3	D1.10.4	D1.10.5	D1.10.6	D1.10.7	D1.10.8	D1.10.9	D1.10.10
D1.10.11	D1.10.12	D1.10.13	D1.10.14	D1.10.15					
D3.1.1	D3.1.2	D3.1.3	D3.8.1	D3.8.2	D3.8.3	D3.8.5	D3.8.6		
D4.1.1	D4.1.2	D4.1.3	D4.1.4	D4.1.5	D4.1.6	D4.1.7	D4.1.8		
D4.2.1	D4.2.2	D4.2.3	D4.2.4	D4.2.5	D4.2.6	D4.2.7	D4.2.8	D4.2.9	D4.2.10
D4.3.1	D4.3.2	D4.3.3	D4.3.4	D4.3.5	D4.3.6	D4.3.7	D4.3.8	D4.3.9	D4.3.10
D4.3.11									
D5.1.1	D5.1.2	D5.1.3	D5.1.4	D5.1.5	D5.1.6	D5.1.7	D5.1.8		
D5.2.1	D5.2.2	D5.2.3	D5.2.4	D5.3.1	D5.3.2	D5.3.3	D5.3.4	D5.3.5	
D5.4.1	D5.4.2	D5.4.3	D5.4.4	D5.4.5	D5.4.6	D5.4.7	D5.4.8	D5.4.9	D5.4.10
D5.5.1	D5.5.2	D5.5.3	D5.5.4	D5.5.5	D5.5.6	D5.6.1	D5.6.2	D5.6.3	D5.6.4
E2.11									
E1.1.1	E1.1.2	E1.1.3	E1.1.5	E1.1.6					
E1.2.1	E1.2.2	E1.2.3	E1.2.5	E1.2.8	E1.2.9	E1.2.10	E1.2.13	E1.2.15	E1.2.17
E1.2.19	E1.2.20	E1.2.21	E1.4.2						
F3									
F1.4	F3.1	F3.2							
F4.1	F4.2	F4.3	F4.4	F4.5	F4.6	F4.7	F4.8	F4.9	F4.10
G2.2	G2.3	G2.5	G2.6	G2.14	G2.15	G2.16			
G2.5.1	G2.5.2	G2.5.3	G2.5.4	G2.5.5	G2.5.6	G2.5.7	G2.5.8	G2.5.9	
G2.6.1	G2.6.2	G2.6.3	G2.6.4	G2.6.5					
H3.8									

5. Plan approval				
B1.7				
B1.7.1	B1.7.2			
E1.3				
E1.1.1	E1.1.2	E1.1.7		
E1.3.1	E1.3.2	E1.3.3	E1.3.4	E1.3.5
E1.3.6	E1.3.7	E1.3.8		
F1.1	F1.2	F1.5	F1.13	
F1.5.1	F1.5.2	F1.5.3		
G2.1	G2.2	G2.3	G2.4	G2.5
G2.6	G2.7	G2.8	G2.9	G2.10
G2.11	G2.12	G2.13	G2.14	G2.15
G2.16	G2.17	G2.18	G2.19	G2.20
G2.21				
G2.5.1	G2.5.2	G2.5.3	G2.5.4	G2.5.5
G2.5.6	G2.5.7	G2.5.8	G2.5.9	
G2.6.1	G2.6.2	G2.6.3	G2.6.4	G2.6.5
G2.7.1	G2.7.2	G2.7.3		
G2.12.1	G2.12.2	G2.12.3	G2.12.4	G2.12.5
G2.12.6	G2.12.7	G2.12.8	G2.12.9	
H3.2	H3.3	H3.9		

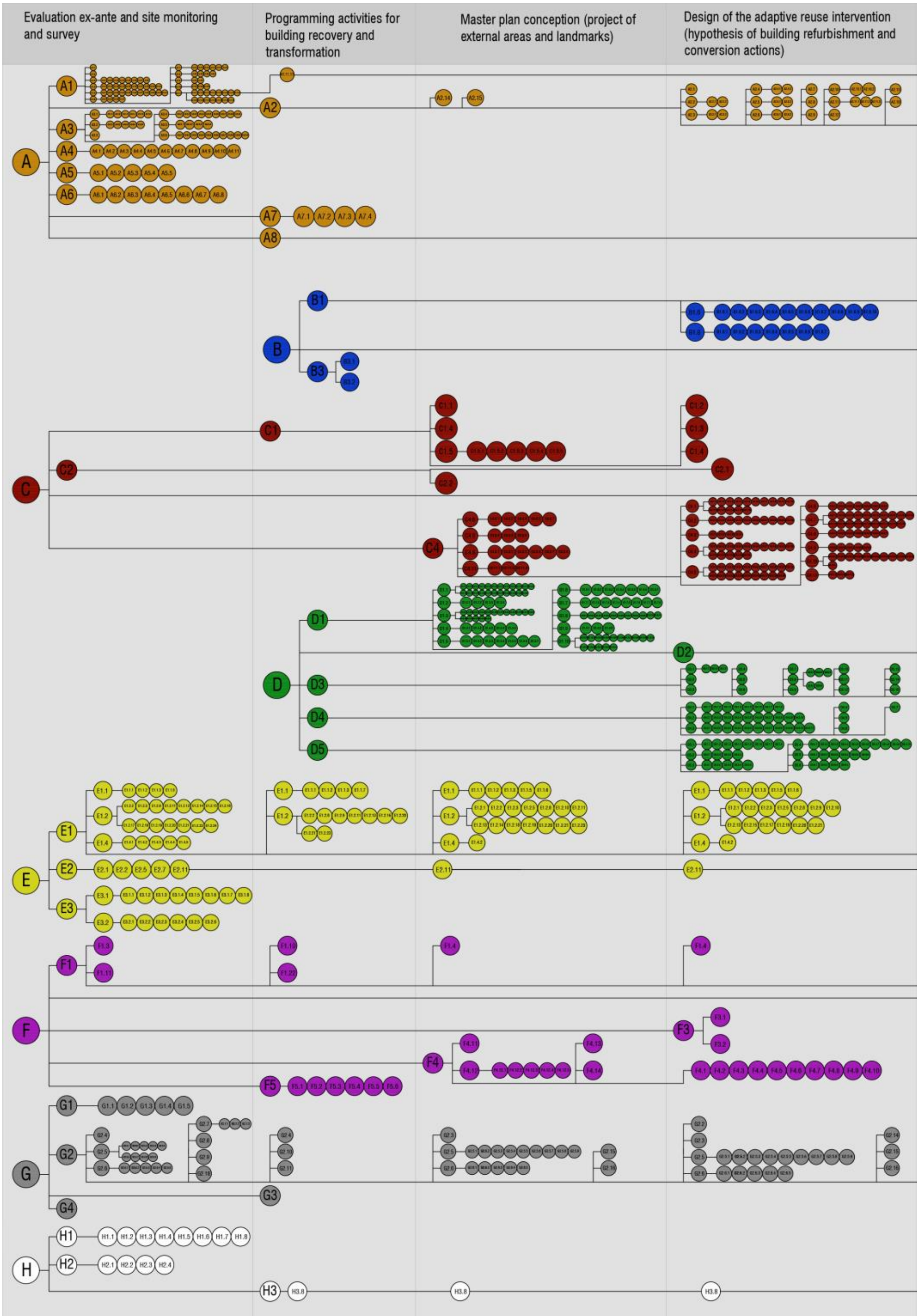
6. Implementation of recovery and reuse interventions on the existing structure and realisation of new buildings									
A2.16	A2.17	A2.18							
A7.1	A7.2	A7.3	A7.4						
A2.16.1	A2.16.2	A2.16.3	A2.16.4	A2.16.5	A2.16.6				
A2.17.1	A2.17.2	A2.17.3	A2.17.4	A2.17.5	A2.17.6	A2.17.7	A2.17.8	A2.17.9	A2.17.10
A2.17.11									
A2.18.1	A2.18.2	A2.18.3	A2.18.4	A2.18.5	A2.18.6	A2.18.7	A2.18.8	A2.18.9	A2.18.10
A2.18.11	A2.18.12	A2.18.13	A2.18.14	A2.18.15	A2.18.16	A2.18.17	A2.18.18	A2.18.19	A2.18.20
A2.18.21	A2.18.22	A2.18.23	A2.18.24	A2.18.25	A2.18.26				
A2.17.1.1	A2.17.1.2	A2.17.1.3	A2.17.1.4	A2.17.1.5	A2.17.1.6	A2.17.1.7			
A2.17.2.1	A2.17.2.2	A2.17.2.3	A2.17.2.4	A2.17.2.5	A2.17.2.6	A2.17.2.7	A2.17.2.8		
A2.17.3.1	A2.17.3.2	A2.17.3.3							
A2.17.4.1	A2.17.4.2	A2.17.4.3	A2.17.4.4	A2.17.4.5	A2.17.4.6	A2.17.4.7			
A2.17.5.1	A2.17.5.2	A2.17.5.3	A2.17.5.4						
A2.17.1.1.1	A2.17.1.1.2	A2.17.1.1.3	A2.17.1.1.4	A2.17.1.1.5					
A2.17.1.2.1	A2.17.1.2.2	A2.17.1.2.3	A2.17.1.2.4	A2.17.1.2.5	A2.17.1.2.6	A2.17.1.2.7	A2.17.1.2.8	A2.17.1.2.9	A2.17.1.2.10
A2.17.1.3.1	A2.17.1.3.2	A2.17.1.3.3	A2.17.1.3.4	A2.17.1.3.5	A2.17.1.3.6	A2.17.1.3.7			
A2.17.2.1.1	A2.17.2.1.2	A2.17.2.1.3	A2.17.2.1.4	A2.17.2.1.5	A2.17.2.1.6				
A2.17.2.2.1	A2.17.2.2.2	A2.17.2.2.3	A2.17.2.2.4	A2.17.2.2.5	A2.17.2.2.6	A2.17.2.2.7	A2.17.2.2.8		
A2.17.2.3.1	A2.17.2.3.2	A2.17.2.3.3	A2.17.2.3.4	A2.17.2.3.5	A2.17.2.3.6	A2.17.2.3.7			
A2.17.2.4.1	A2.17.2.4.2	A2.17.2.4.3							
A2.17.2.6.1	A2.17.2.6.2	A2.17.2.6.3	A2.17.2.6.4	A2.17.2.6.5	A2.17.2.6.6				
B1.1	B1.2	B1.4	B1.5	B1.9	B1.10	B1.11	B1.12		
B1.1.1	B1.1.2	B1.1.3	B1.1.4	B1.1.5					
B1.2.1	B1.2.2	B1.2.3	B1.2.4	B1.2.5	B1.2.6	B1.2.7	B1.2.8	B1.2.9	B1.2.10
B1.2.11	B1.2.12	B1.2.13	B1.2.14	B1.2.15	B1.2.16	B1.2.17	B1.2.18	B1.2.19	B1.2.20
B1.2.21	B1.2.22								
B1.4.1	B1.4.2	B1.4.3	B1.4.4	B1.5.1	B1.5.2	B1.5.3	B1.5.4		
C3									
D2.1	D2.2	D2.3	D2.4						
D2.2.1	D2.2.2	D2.2.3	D2.2.4	D2.2.5	D2.2.6	D2.2.7	D2.2.8	D2.2.9	
E1.1.1	E1.1.2	E1.1.3	E1.1.4	E1.1.5	E1.1.6				
E1.2.2	E1.2.3	E1.2.4	E1.2.6	E1.2.7	E1.2.9	E1.2.10	E1.2.11	E1.2.12	E1.2.13
E1.2.14	E1.2.15	E1.2.16	E1.2.18	E1.2.20	E1.2.21	E1.2.22	E1.2.23		
F1.6	F1.7	F1.12	F1.14	F1.15	F1.16	F1.17	F1.18	F1.19	F1.20
F1.21									
F1.7.1	F1.7.2	F1.7.3	F1.7.4	F1.7.5	F1.7.6	F1.7.7	F1.7.8	F1.7.9	F1.7.10
F1.7.11	F1.7.12	F1.7.13	F1.7.14	F1.7.15	F1.7.16	F1.7.17	F1.7.18		
F1.12.1	F1.12.2	F1.12.3	F1.12.4	F1.12.5	F1.12.6				
F1.15.1	F1.15.2	F1.15.3	F1.15.4	F1.15.5	F1.15.6	F1.15.7	F1.15.8	F1.15.9	F1.15.10
F1.15.11									
F1.15.1.1	F1.15.1.2	F1.15.1.3	F1.15.1.4	F1.15.1.5	F1.15.1.6	F1.15.1.7			
F1.15.2.1	F1.15.2.2	F1.15.2.3	F1.15.2.4	F1.15.2.5	F1.15.2.6	F1.15.2.7	F1.15.2.8		
G2.1	G2.2	G2.3	G2.4	G2.11	G2.14	G2.15	G2.16	G2.18	
H3.1	H3.3	H3.4	H3.5	H3.6	H3.10				

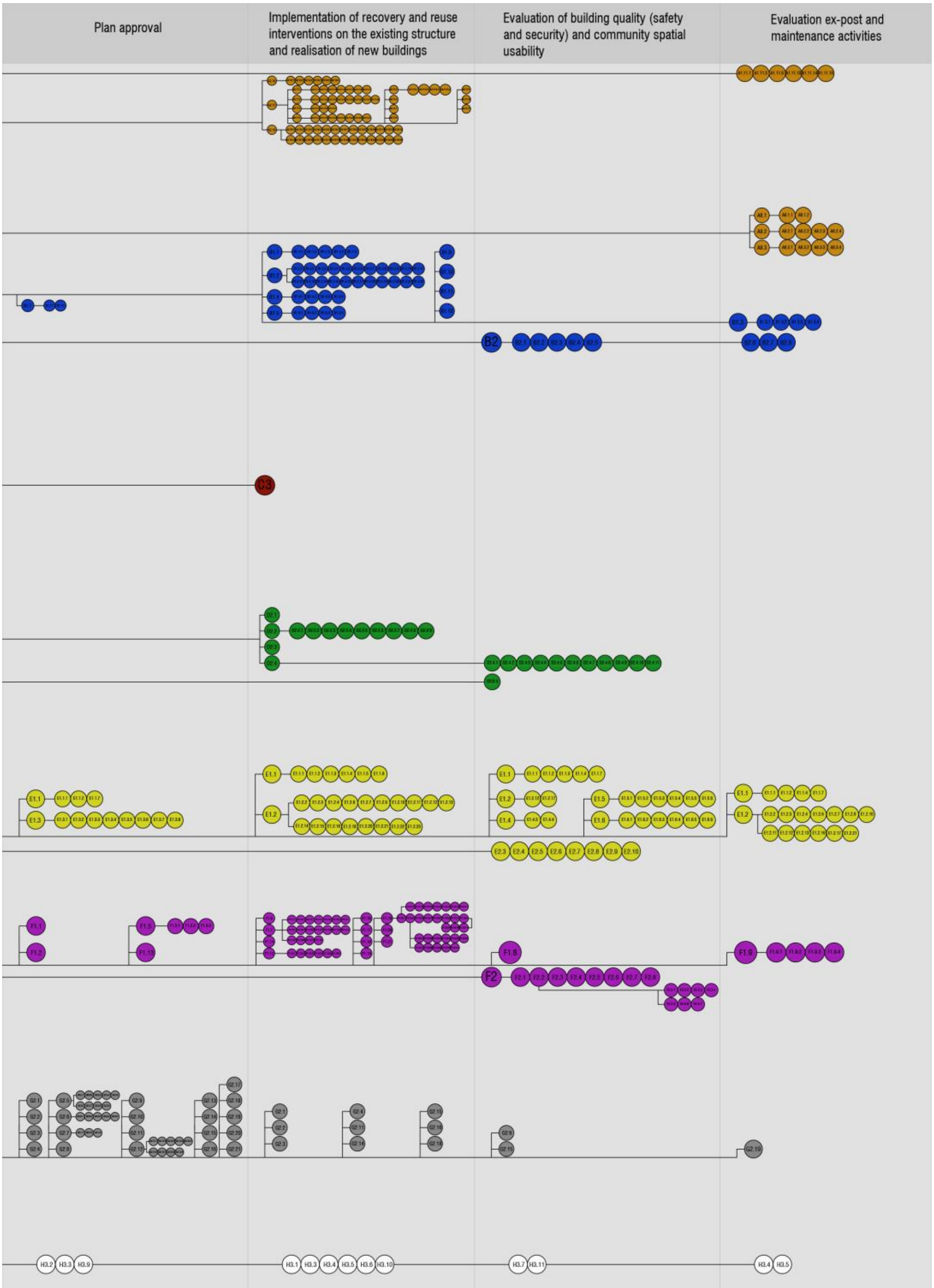
7. Evaluation of building quality (safety and security) and community spatial usability				
B2				
B2.1	B2.2	B2.3	B2.4	B2.5
D2.4.1	D2.4.2	D2.4.3	D2.4.4	D2.4.5
D2.4.6	D2.4.7	D2.4.8	D2.4.9	D2.4.10
D2.4.11				
D3.8.4				
E1.5	E1.6			
E2.3	E2.4	E2.5	E2.6	E2.7
E2.8	E2.9	E2.10		
E1.1.1	E1.1.2	E1.1.3	E1.1.4	E1.1.7
E1.2.12	E1.2.17			
E1.4.3	E1.4.4			
E1.5.1	E1.5.2	E1.5.3	E1.5.4	E1.5.5
E1.5.6				
E1.6.1	E1.6.2	E1.6.3	E1.6.4	E1.6.5
E1.6.6				
F2				
F1.8				
F2.1	F2.2	F2.3	F2.4	F2.5
F2.6	F2.7	F2.8		
F2.2.1	F2.2.2	F2.2.3	F2.2.4	F2.2.5
F2.2.6	F2.2.7			
G2.9	G2.15			
H3.7	H3.11			

8. Evaluation ex-post and activation of ordinary and extraordinary maintenance activities				
A1.11				
A8.1	A8.2	A8.3		
A1.11.1	A1.11.5	A1.11.6	A1.11.10	A1.11.14
A1.11.15				
A8.1.1	A8.1.2			
A8.2.1	A8.2.2	A8.2.3	A8.2.4	
A8.3.1	A8.3.2	A8.3.3	A8.3.4	
B1.3				
B2.6	B2.7	B2.8		
B1.3.1	B1.3.2	B1.3.3	B1.3.4	
E1.1.1	E1.1.2	E1.1.4	E1.1.7	
E1.2.2	E1.2.3	E1.2.4	E1.2.6	E1.2.7
E1.2.9	E1.2.10	E1.2.11	E1.2.12	E1.2.13
E1.2.16	E1.2.17	E1.2.21		
F1.9				
F1.9.1	F1.9.2	F1.9.3	F1.9.4	
G2.19				
H3.4	H3.5			

ANNEX C-b

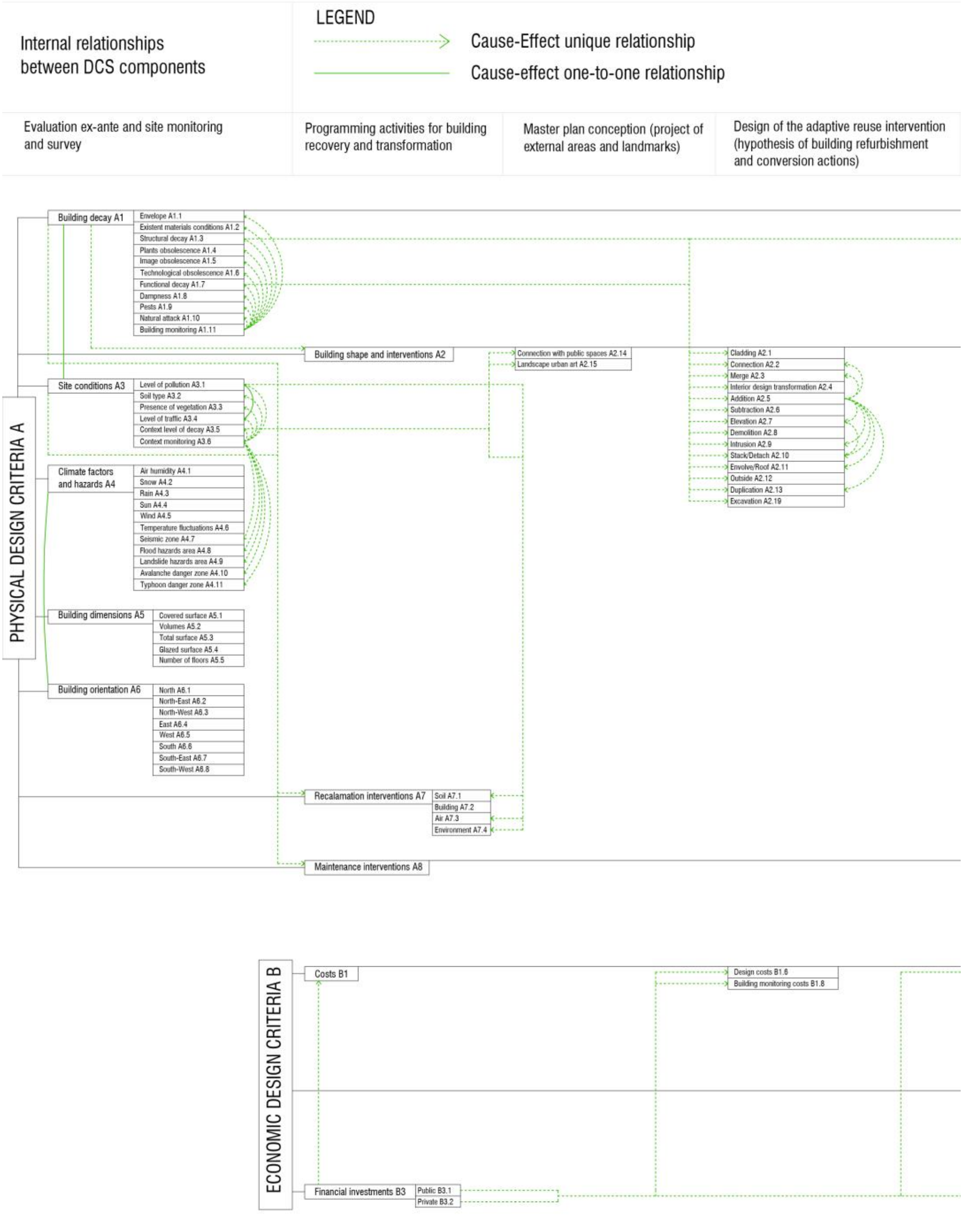
(DCS parameters flowchart – simplified version until sub-attributes 1)

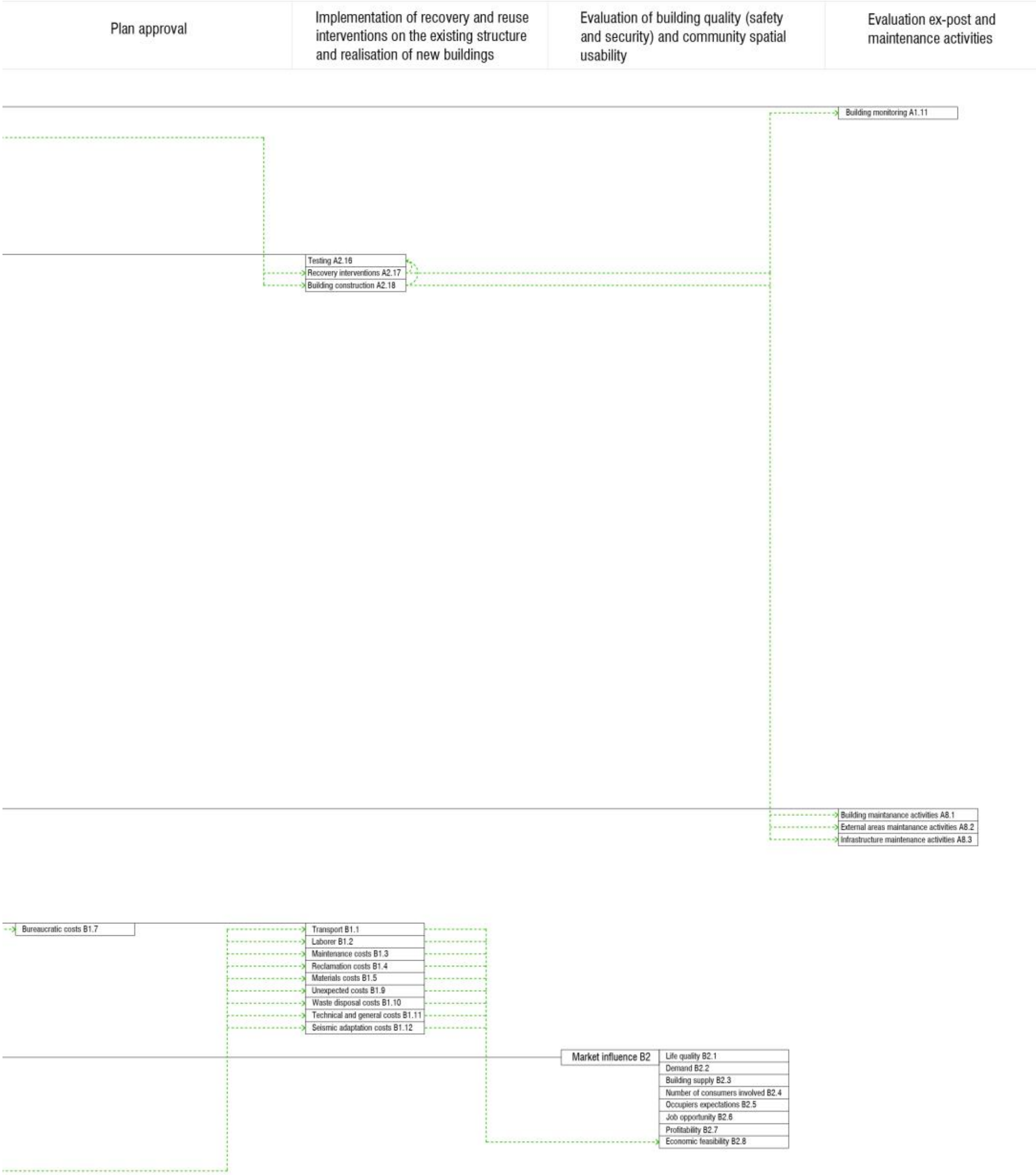

Evaluation ex-ante and site monitoring and survey
Programming activities for building recovery and transformation
Master plan conception (project of external areas and landmarks)
Design of the adaptive reuse intervention (hypothesis of building refurbishment and conversion actions)
A
A1
A2
A3
A4
A5
A6
A7
A8
A7.1
A7.2
A7.3
A7.4
B
B1
B3
C
C1
C2
C4
D
D1
D2
D3
D4
D5
E
E1
E2
E3
E1.1
E1.2
E1.4
E2.1
E2.2
E2.5
E2.7
E2.11
E3.1
E3.2
F
F1
F3
F4
F5
F5.1
F5.2
F5.3
F5.4
F5.5
F5.6
F4.1
F4.2
F4.3
F4.4
F4.5
F4.6
F4.7
F4.8
F4.9
F4.10
G
G1
G2
G3
G4
G1.1
G1.2
G1.3
G1.4
G1.5
H
H1
H2
H3
H1.1
H1.2
H1.3
H1.4
H1.5
H1.6
H1.7
H1.8
H2.1
H2.2
H2.3
H2.4


Plan approval
Implementation of recovery and reuse interventions on the existing structure and realisation of new buildings
Evaluation of building quality (safety and security) and community spatial usability
Evaluation ex-post and maintenance activities
B2
C3
F1.8
F2
F1.9
H3.2
H3.3
H3.9
H3.1
H3.3
H3.4
H3.5
H3.6
H3.10
H3.7
H3.11
H3.4
H3.5

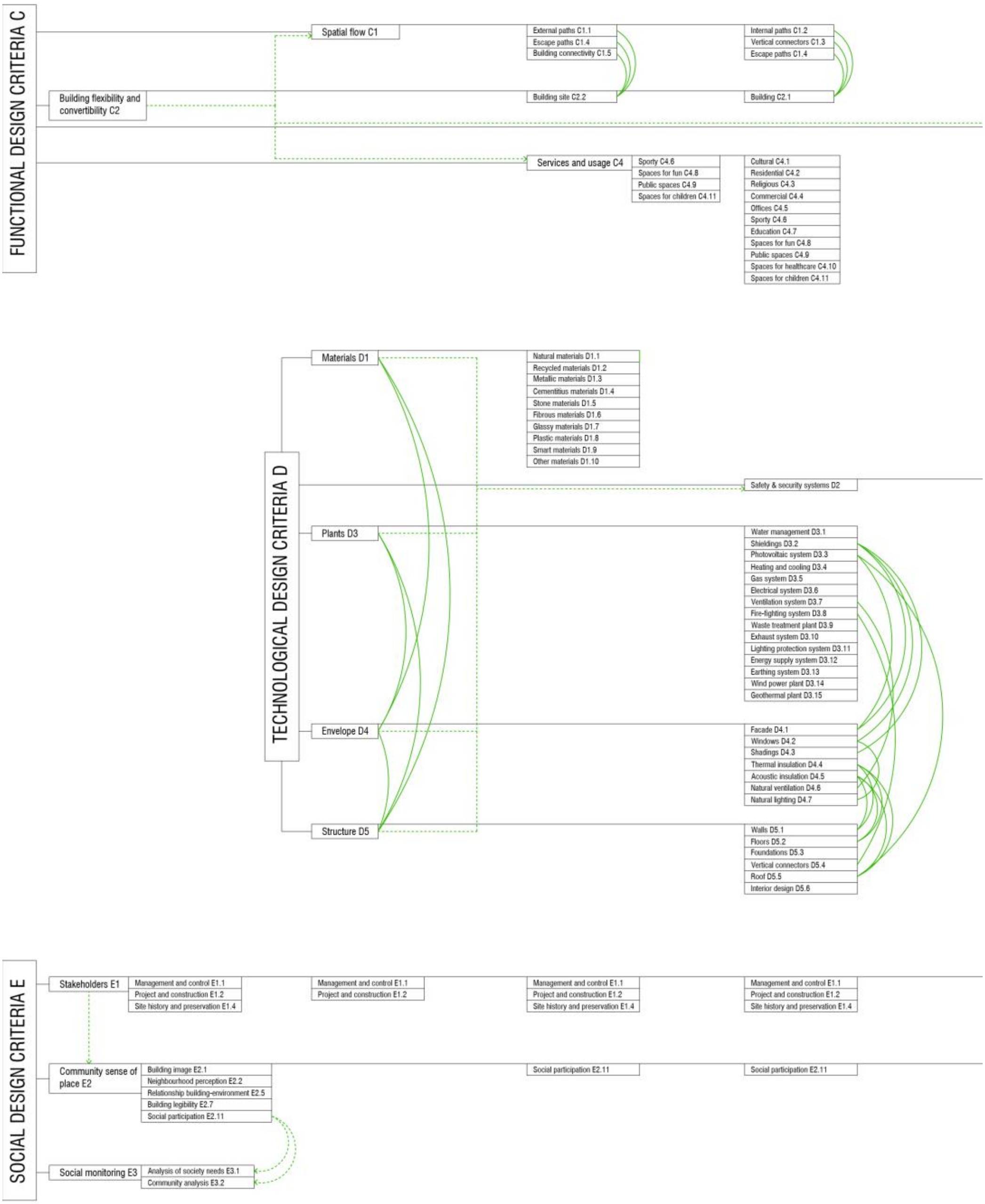
ANNEX C-c

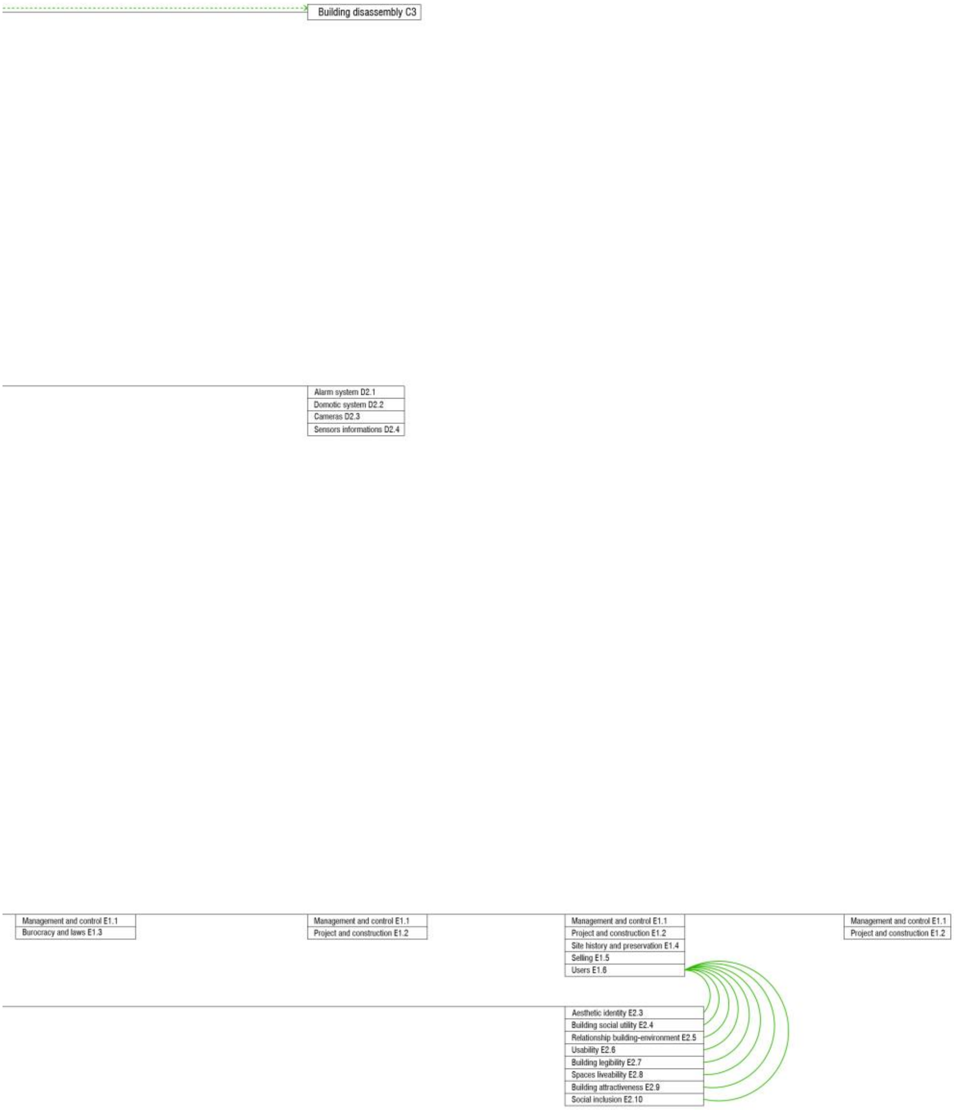
(Internal and external – unique and one-to-one DCS features cause-and-effect connections and relationships)


Internal relationships between DCS components
LEGEND
Cause-Effect unique relationship
Cause-effect one-to-one relationship
Evaluation ex-ante and site monitoring and survey
Programming activities for building recovery and transformation
Master plan conception (project of external areas and landmarks)
Design of the adaptive reuse intervention (hypothesis of building refurbishment and conversion actions)
PHYSICAL DESIGN CRITERIA A
Building decay A1
Envelope A1.1
Existent materials conditions A1.2
Structural decay A1.3
Plants obsolescence A1.4
Image obsolescence A1.5
Technological obsolescence A1.6
Functional decay A1.7
Dampness A1.8
Pests A1.9
Natural attack A1.10
Building monitoring A1.11
Building shape and interventions A2
Connection with public spaces A2.14
Landscape urban art A2.15
Cladding A2.1
Connection A2.2
Merge A2.3
Interior design transformation A2.4
Addition A2.5
Subtraction A2.6
Elevation A2.7
Demolition A2.8
Intrusion A2.9
Stack/Detach A2.10
Envolve/Roof A2.11
Outside A2.12
Duplication A2.13
Excavation A2.19
Site conditions A3
Level of pollution A3.1
Soil type A3.2
Presence of vegetation A3.3
Level of traffic A3.4
Context level of decay A3.5
Context monitoring A3.6
Climate factors and hazards A4
Air humidity A4.1
Snow A4.2
Rain A4.3
Sun A4.4
Wind A4.5
Temperature fluctuations A4.6
Seismic zone A4.7
Flood hazards area A4.8
Landslide hazards area A4.9
Avalanche danger zone A4.10
Typhoon danger zone A4.11
Building dimensions A5
Covered surface A5.1
Volumes A5.2
Total surface A5.3
Glazed surface A5.4
Number of floors A5.5
Building orientation A6
North A6.1
North-East A6.2
North-West A6.3
East A6.4
West A6.5
South A6.6
South-East A6.7
South-West A6.8
Recalamation interventions A7
Soil A7.1
Building A7.2
Air A7.3
Environment A7.4
Maintenance interventions A8
ECONOMIC DESIGN CRITERIA B
Costs B1
Design costs B1.6
Building monitoring costs B1.8
Financial investments B3
Public B3.1
Private B3.2

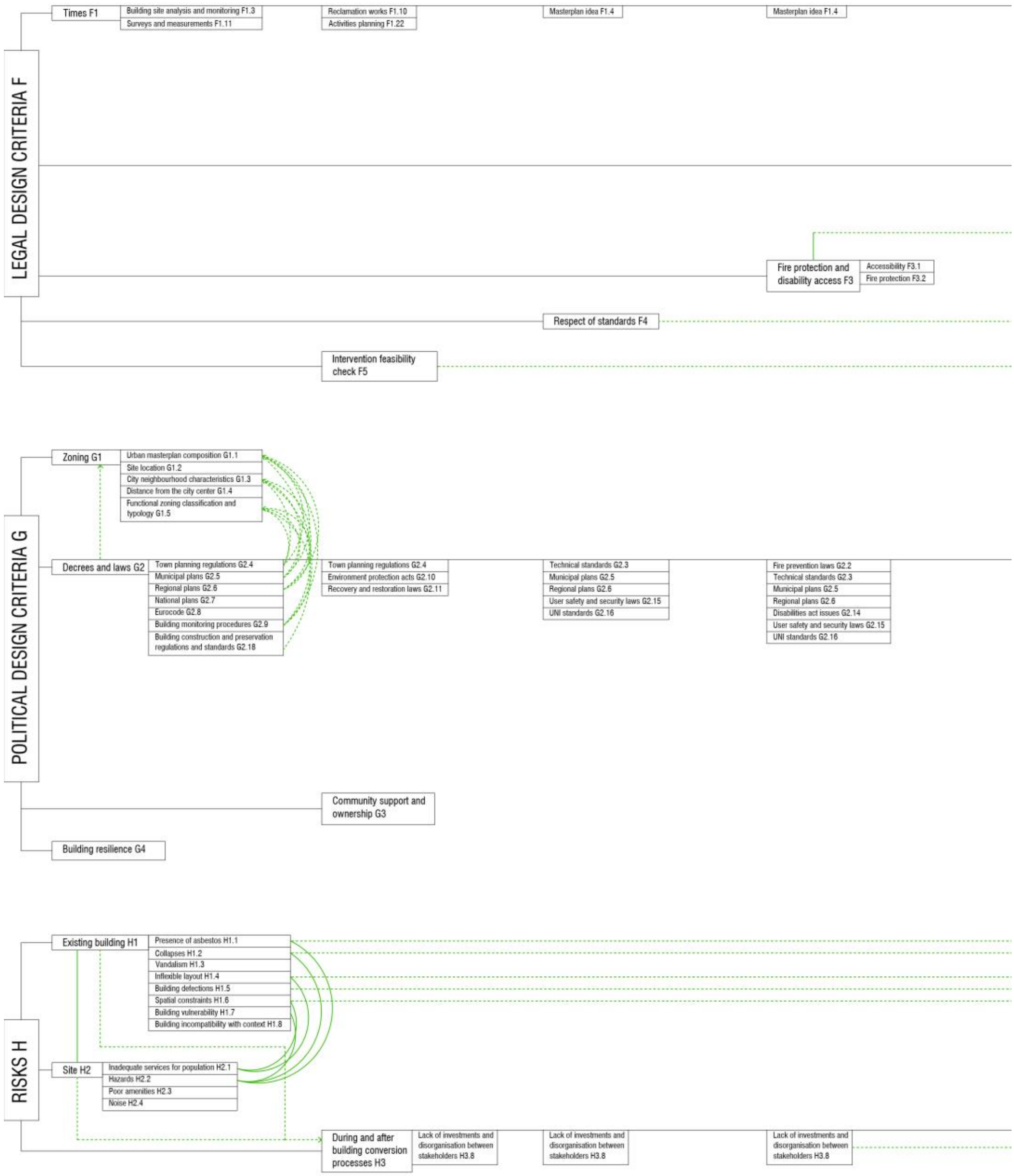


Plan approval
Implementation of recovery and reuse interventions on the existing structure and realisation of new buildings
Evaluation of building quality (safety and security) and community spatial usability
Evaluation ex-post and maintenance activities
Building monitoring A1.11
Testing A2.16
Recovery interventions A2.17
Building construction A2.18
Building maintanance activities A8.1
External areas maintanance activities A8.2
Infrastructure maintenance activities A8.3
Bureaucratic costs B1.7
Transport B1.1
Laborer B1.2
Maintenance costs B1.3
Reclamation costs B1.4
Materials costs B1.5
Unexpected costs B1.9
Waste disposal costs B1.10
Technical and general costs B1.11
Seismic adaptation costs B1.12
Market influence B2
Life quality B2.1
Demand B2.2
Building supply B2.3
Number of consumers involved B2.4
Occupiers expectations B2.5
Job opportunity B2.6
Profitability B2.7
Economic feasibility B2.8


FUNCTIONAL DESIGN CRITERIA C
Spatial flow C1
External paths C1.1
Escape paths C1.4
Building connectivity C1.5
Internal paths C1.2
Vertical connectors C1.3
Escape paths C1.4
Building flexibility and convertibility C2
Building site C2.2
Building C2.1
Services and usage C4
Sporty C4.6
Spaces for fun C4.8
Public spaces C4.9
Spaces for children C4.11
Cultural C4.1
Residential C4.2
Religious C4.3
Commercial C4.4
Offices C4.5
Sporty C4.6
Education C4.7
Spaces for fun C4.8
Public spaces C4.9
Spaces for healthcare C4.10
Spaces for children C4.11
TECHNOLOGICAL DESIGN CRITERIA D
Materials D1
Natural materials D1.1
Recycled materials D1.2
Metallic materials D1.3
Cementitius materials D1.4
Stone materials D1.5
Fibrous materials D1.6
Glassy materials D1.7
Plastic materials D1.8
Smart materials D1.9
Other materials D1.10
Safety & security systems D2
Plants D3
Water management D3.1
Shieldings D3.2
Photovoltaic system D3.3
Heating and cooling D3.4
Gas system D3.5
Electrical system D3.6
Ventilation system D3.7
Fire-fighting system D3.8
Waste treatment plant D3.9
Exhaust system D3.10
Lighting protection system D3.11
Energy supply system D3.12
Earthing system D3.13
Wind power plant D3.14
Geothermal plant D3.15
Envelope D4
Facade D4.1
Windows D4.2
Shadings D4.3
Thermal insulation D4.4
Acoustic insulation D4.5
Natural ventilation D4.6
Natural lighting D4.7
Structure D5
Walls D5.1
Floors D5.2
Foundations D5.3
Vertical connectors D5.4
Roof D5.5
Interior design D5.6
SOCIAL DESIGN CRITERIA E
Stakeholders E1
Management and control E1.1
Project and construction E1.2
Site history and preservation E1.4
Management and control E1.1
Project and construction E1.2
Management and control E1.1
Project and construction E1.2
Site history and preservation E1.4
Management and control E1.1
Project and construction E1.2
Site history and preservation E1.4
Community sense of place E2
Building image E2.1
Neighbourhood perception E2.2
Relationship building-environment E2.5
Building legibility E2.7
Social participation E2.11
Social participation E2.11
Social participation E2.11
Social monitoring E3
Analysis of society needs E3.1
Community analysis E3.2



Building disassembly C3
Alarm system D2.1
Domotic system D2.2
Cameras D2.3
Sensors informations D2.4
Management and control E1.1
Burocracy and laws E1.3
Management and control E1.1
Project and construction E1.2
Management and control E1.1
Project and construction E1.2
Site history and preservation E1.4
Selling E1.5
Users E1.6
Management and control E1.1
Project and construction E1.2
Aesthetic identity E2.3
Building social utility E2.4
Relationship building-environment E2.5
Usability E2.6
Building legibility E2.7
Spaces liveability E2.8
Building attractiveness E2.9
Social inclusion E2.10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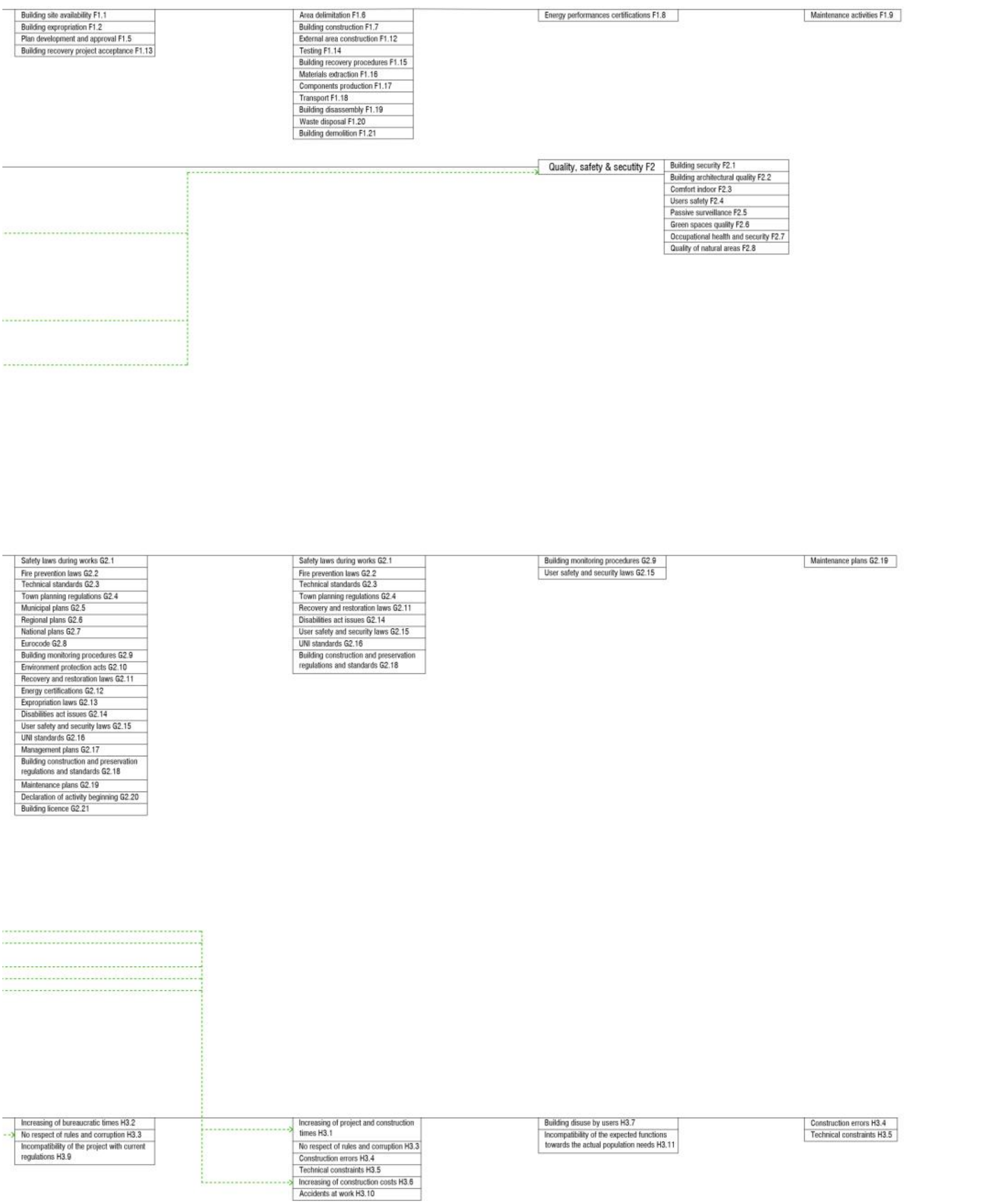

Building site availability F1.1
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Incompatibility of the expected functions towards the actual population needs H3.11
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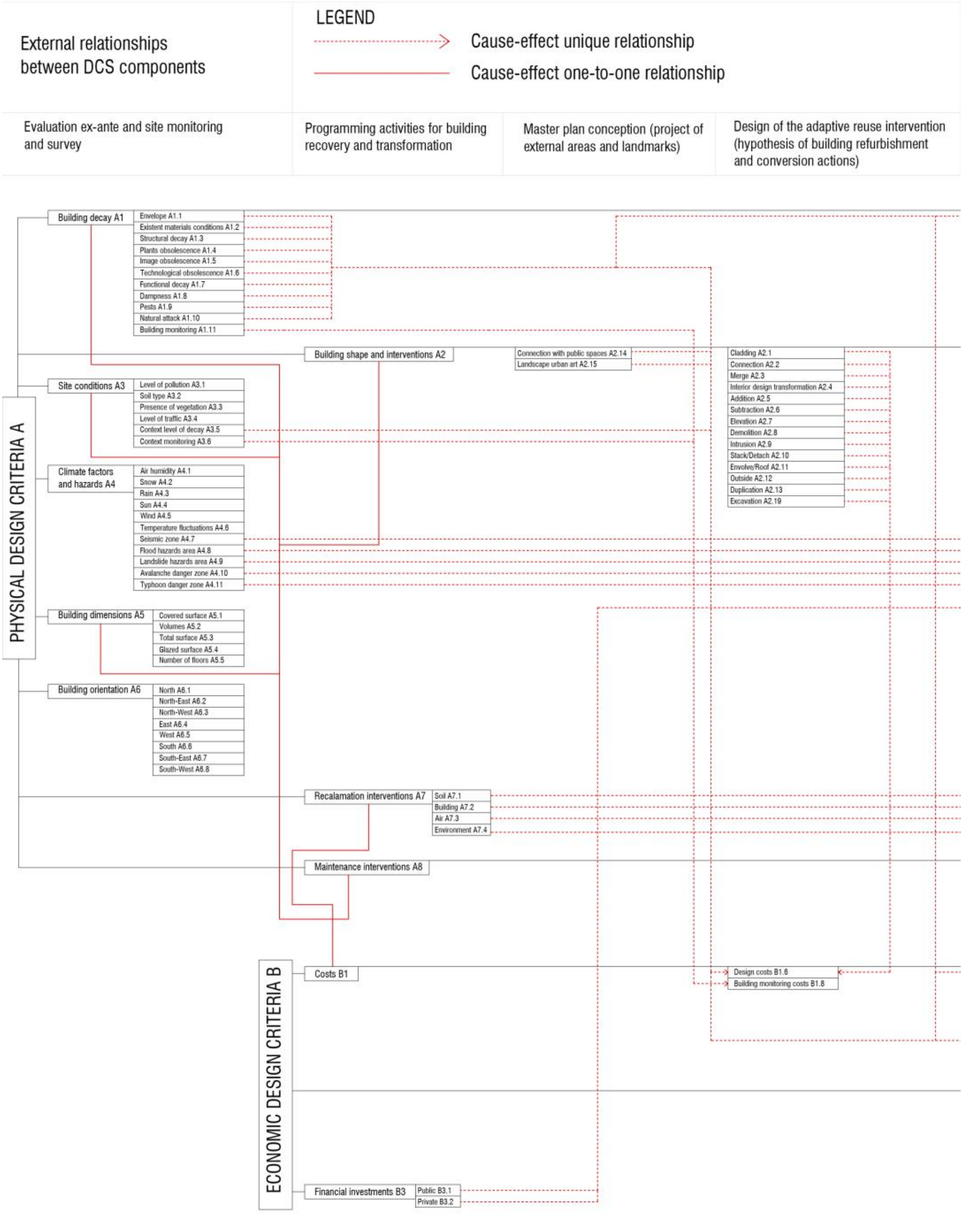

External relationships between DCS components
LEGEND
Cause-effect unique relationship
Cause-effect one-to-one relationship
Evaluation ex-ante and site monitoring and survey
Programming activities for building recovery and transformation
Master plan conception (project of external areas and landmarks)
Design of the adaptive reuse intervention (hypothesis of building refurbishment and conversion actions)
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Number of floors A5.5
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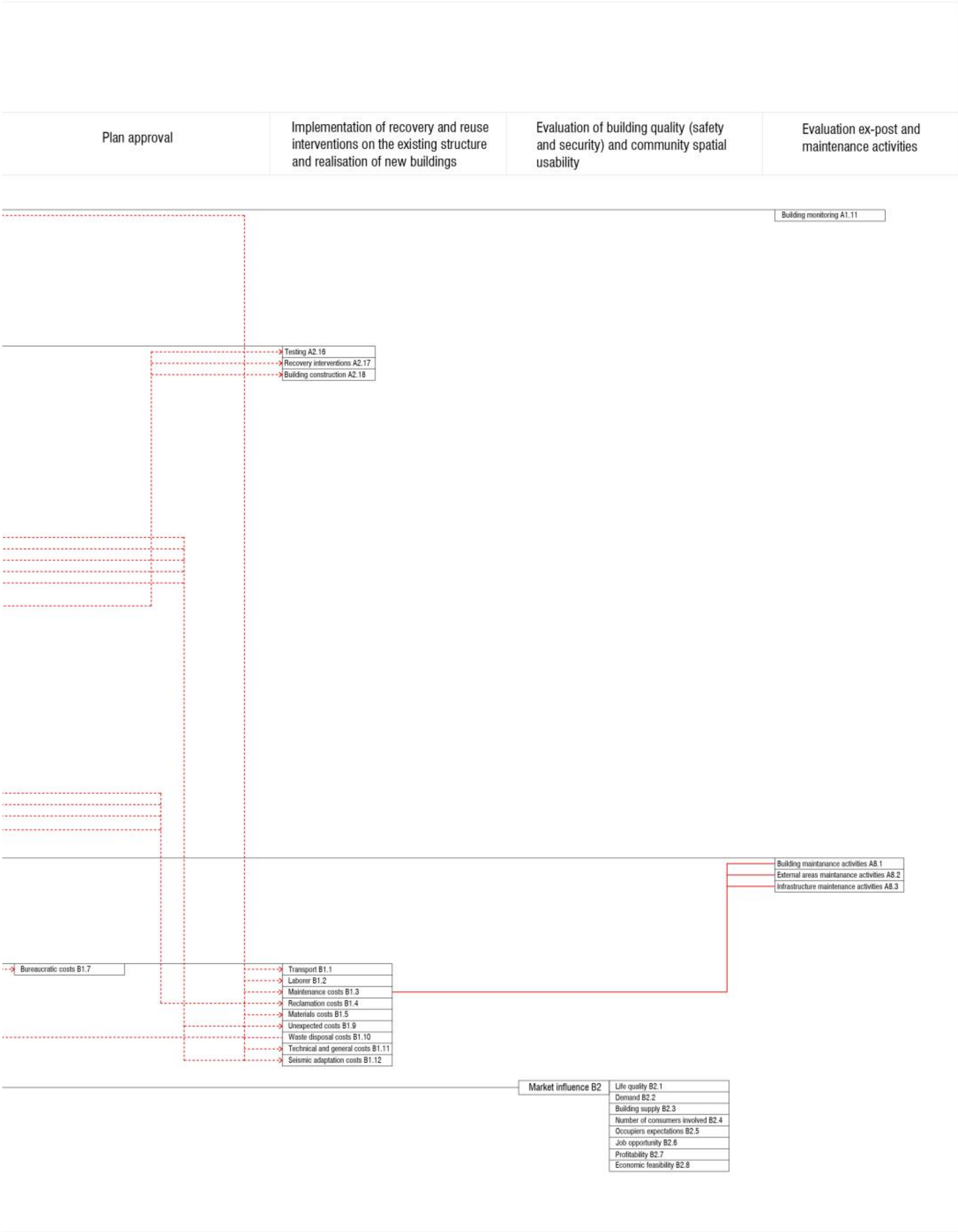
Design costs B1.6
Building monitoring costs B1.8
Financial investments B3
Public B3.1
Private B3.2


Plan approval
Implementation of recovery and reuse interventions on the existing structure and realisation of new buildings
Evaluation of building quality (safety and security) and community spatial usability
Evaluation ex-post and maintenance activities
Building monitoring A1.11
Testing A2.16
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Waste disposal costs B1.10
Technical and general costs B1.11
Seismic adaptation costs B1.12
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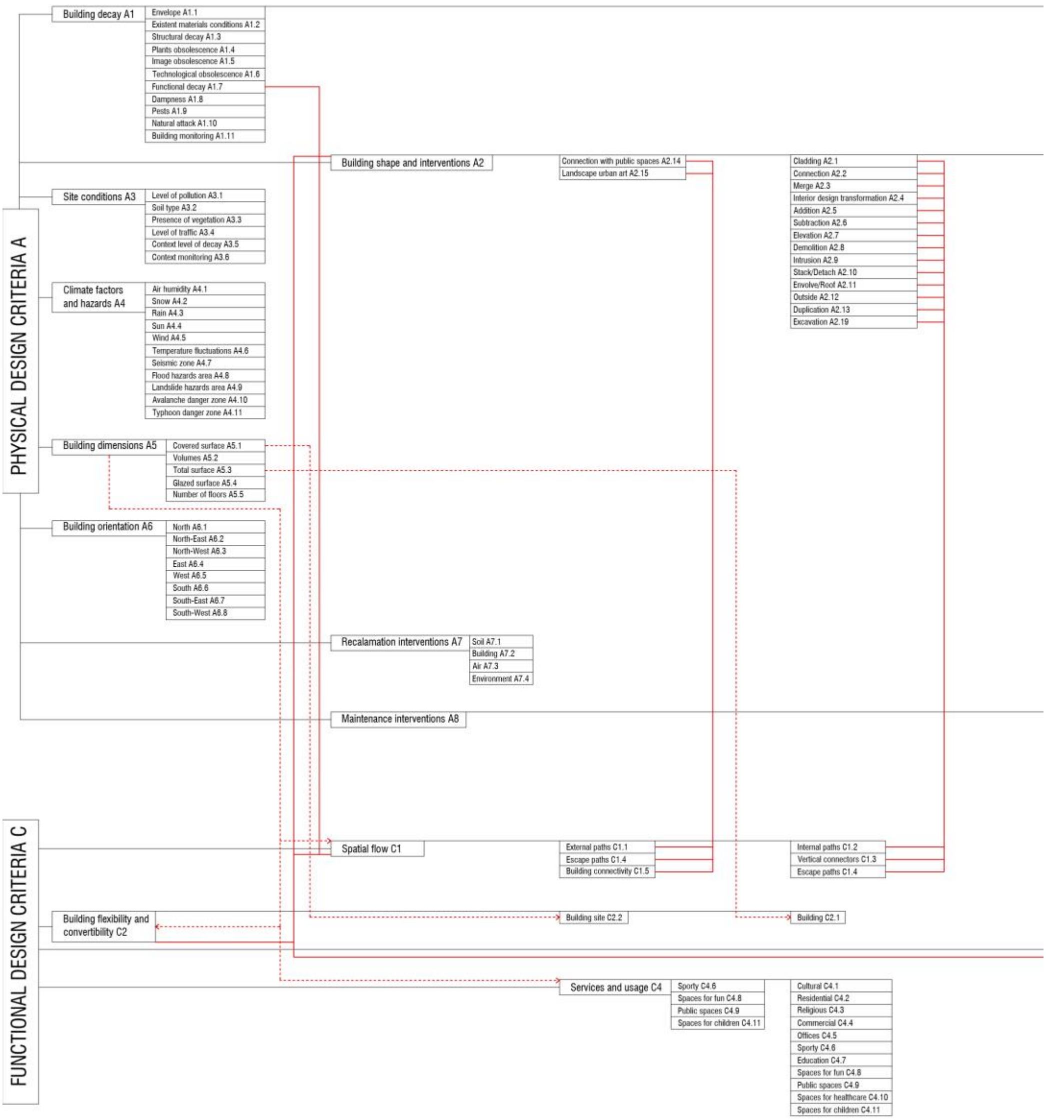
Life quality B2.1
Demand B2.2
Building supply B2.3
Number of consumers involved B2.4
Occupiers expectations B2.5
Job opportunity B2.6
Profitability B2.7
Economic feasibility B2.8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Building connectivity C1.5
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Building maintanance activities A8.1
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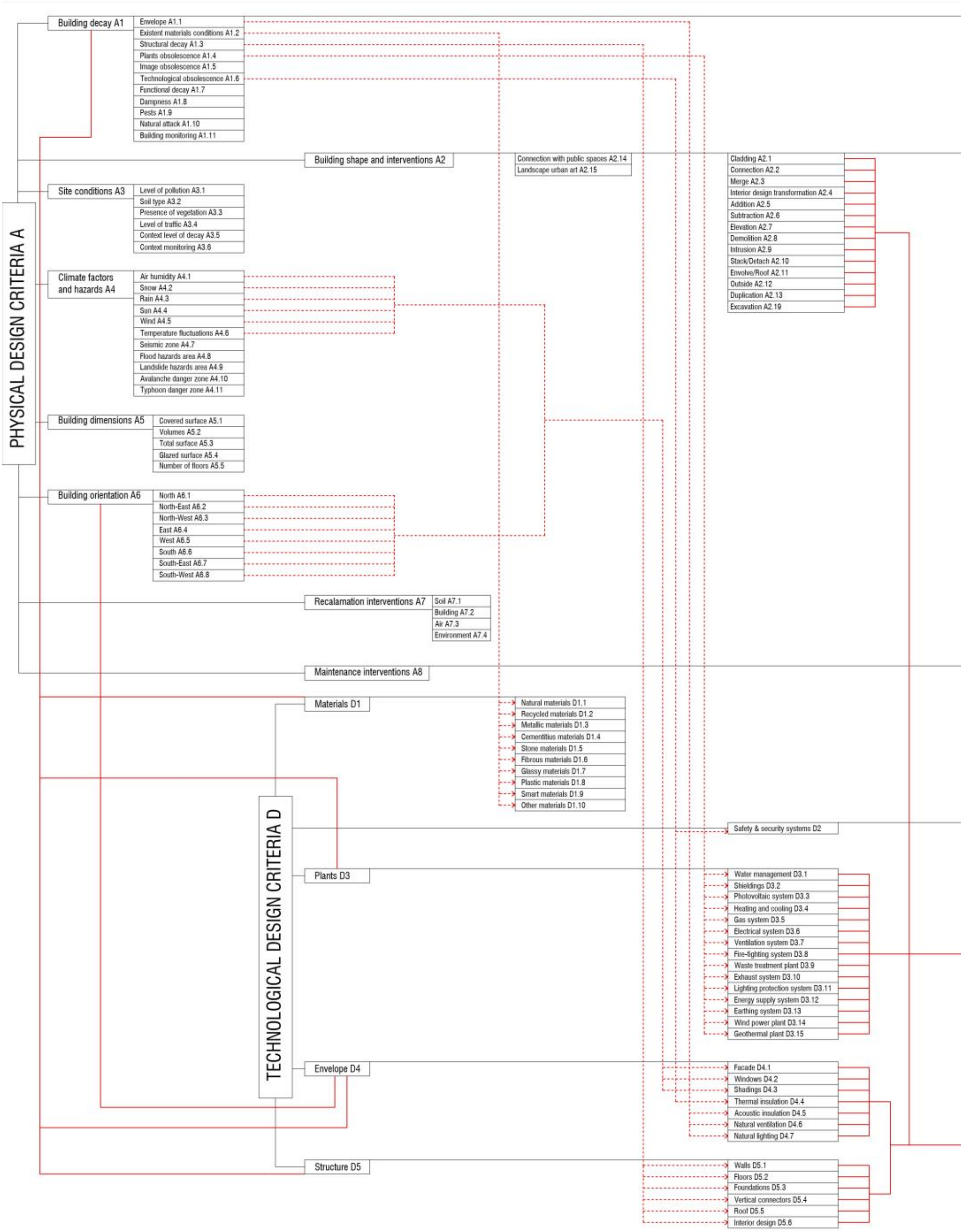
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Building decay A1
Envelope A1.1
Existent materials conditions A1.2
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Plants obsolescence A1.4
Image obsolescence A1.5
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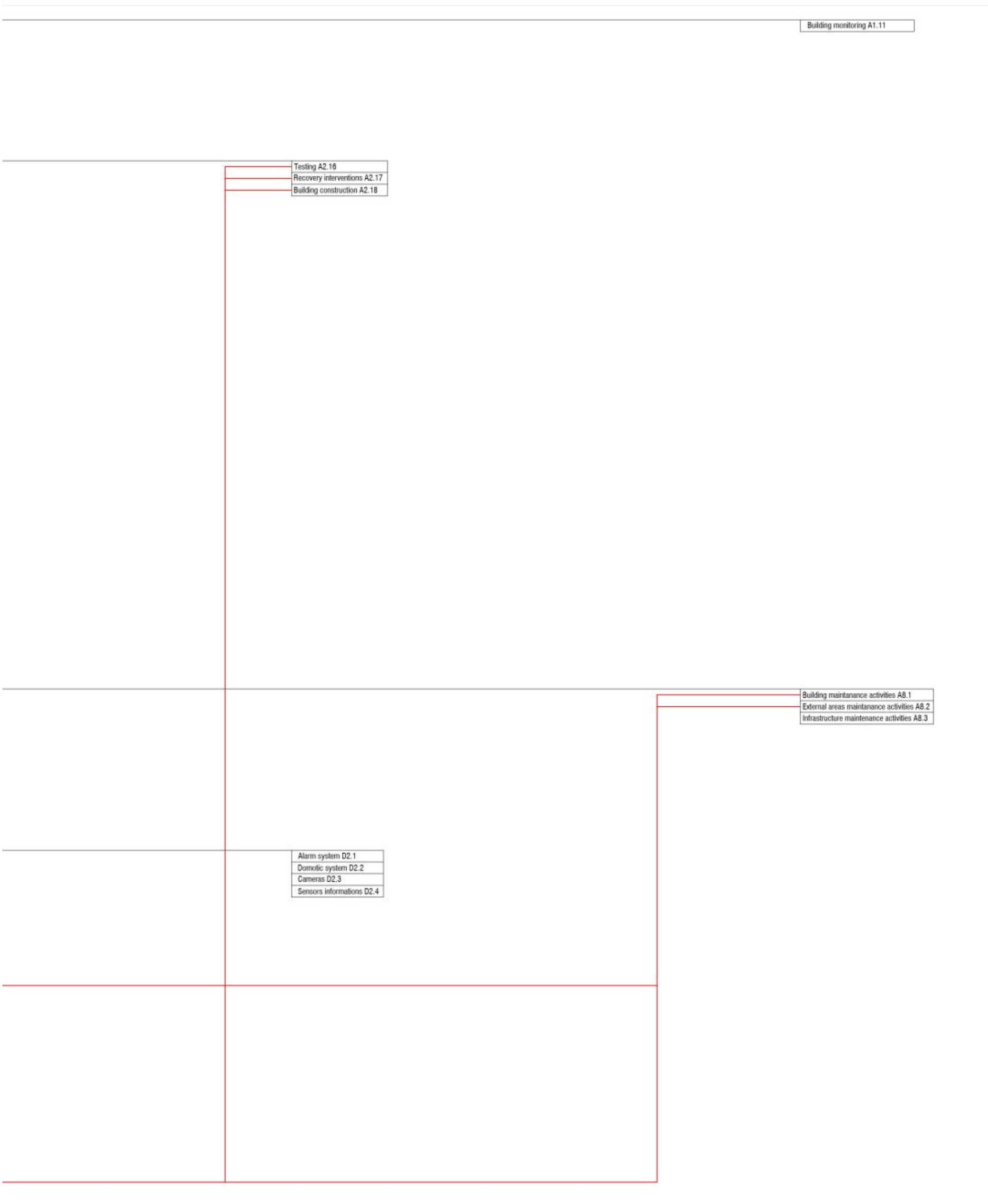
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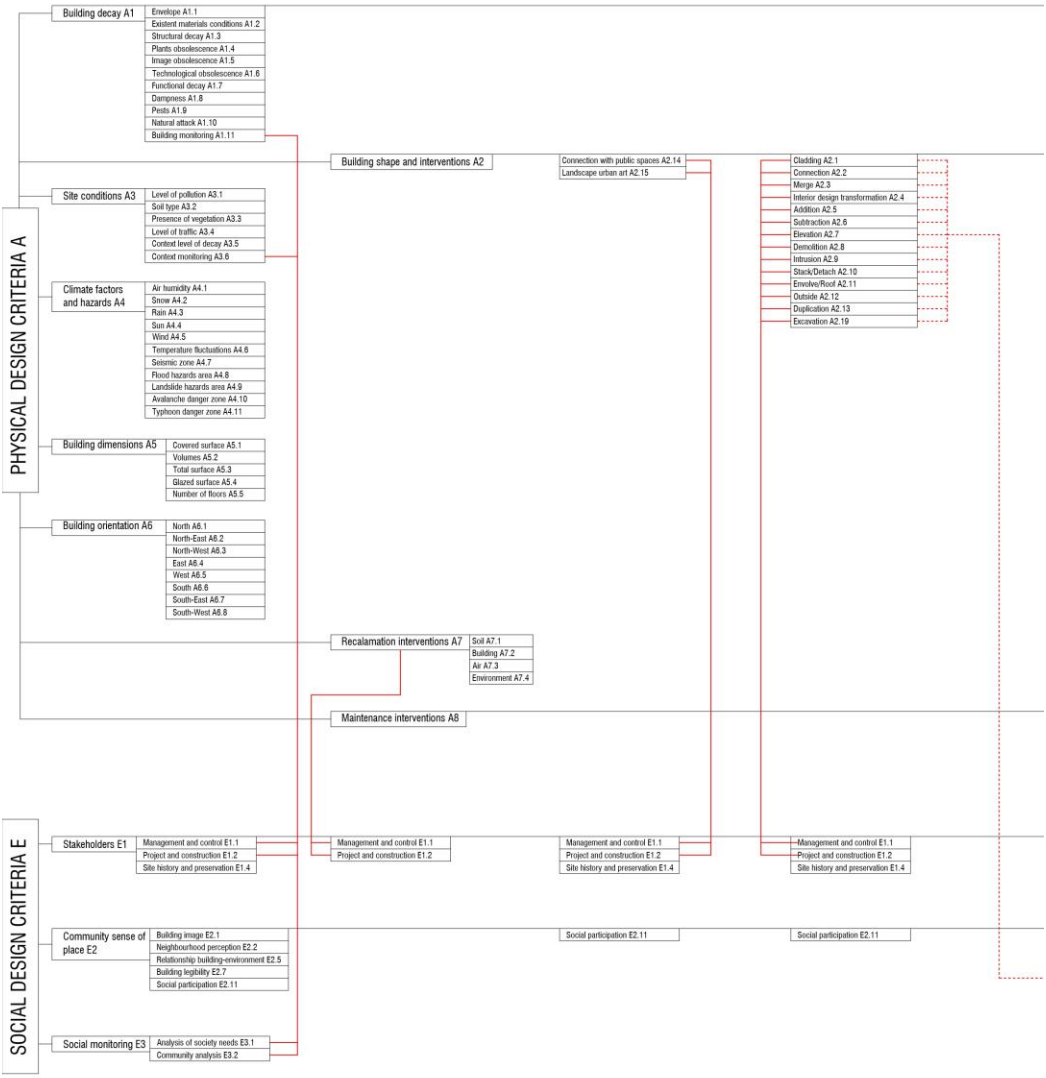
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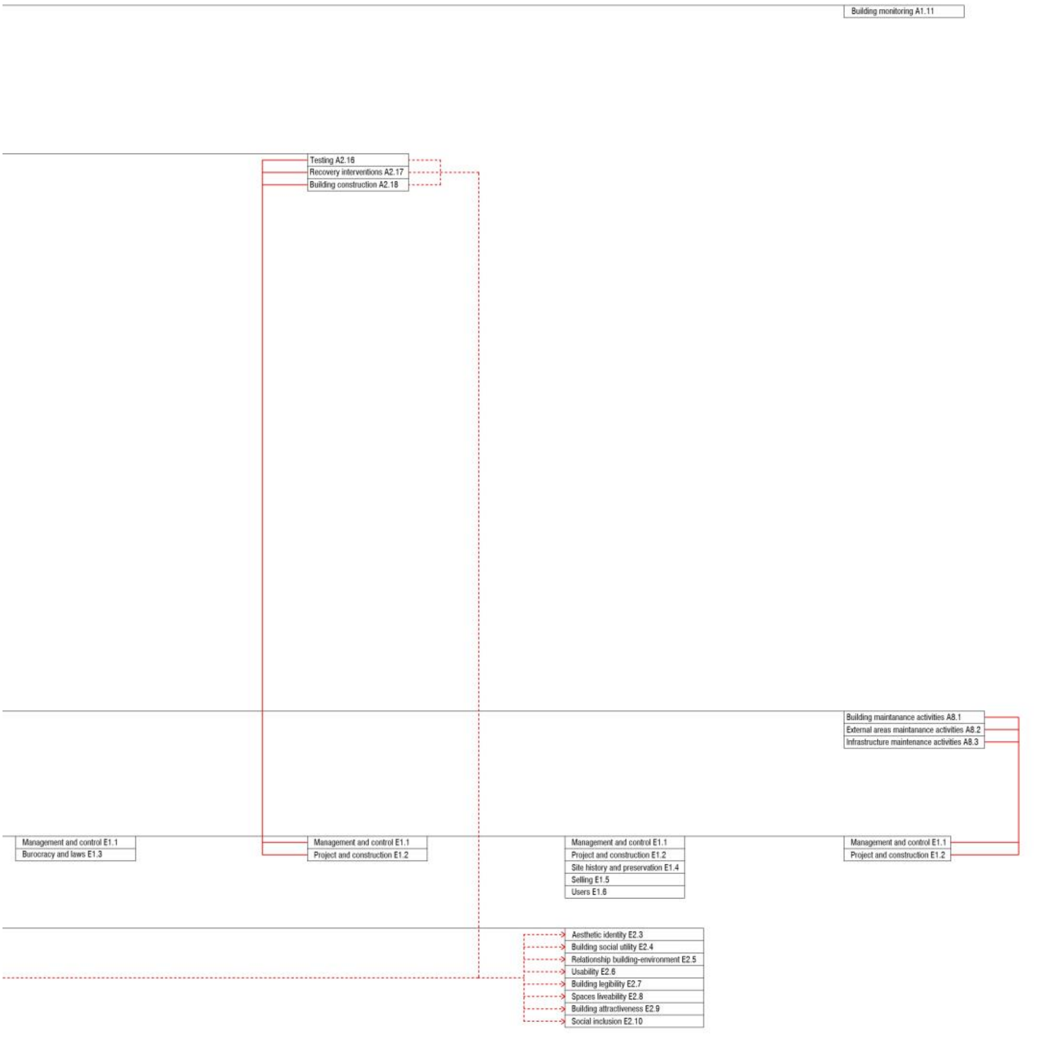
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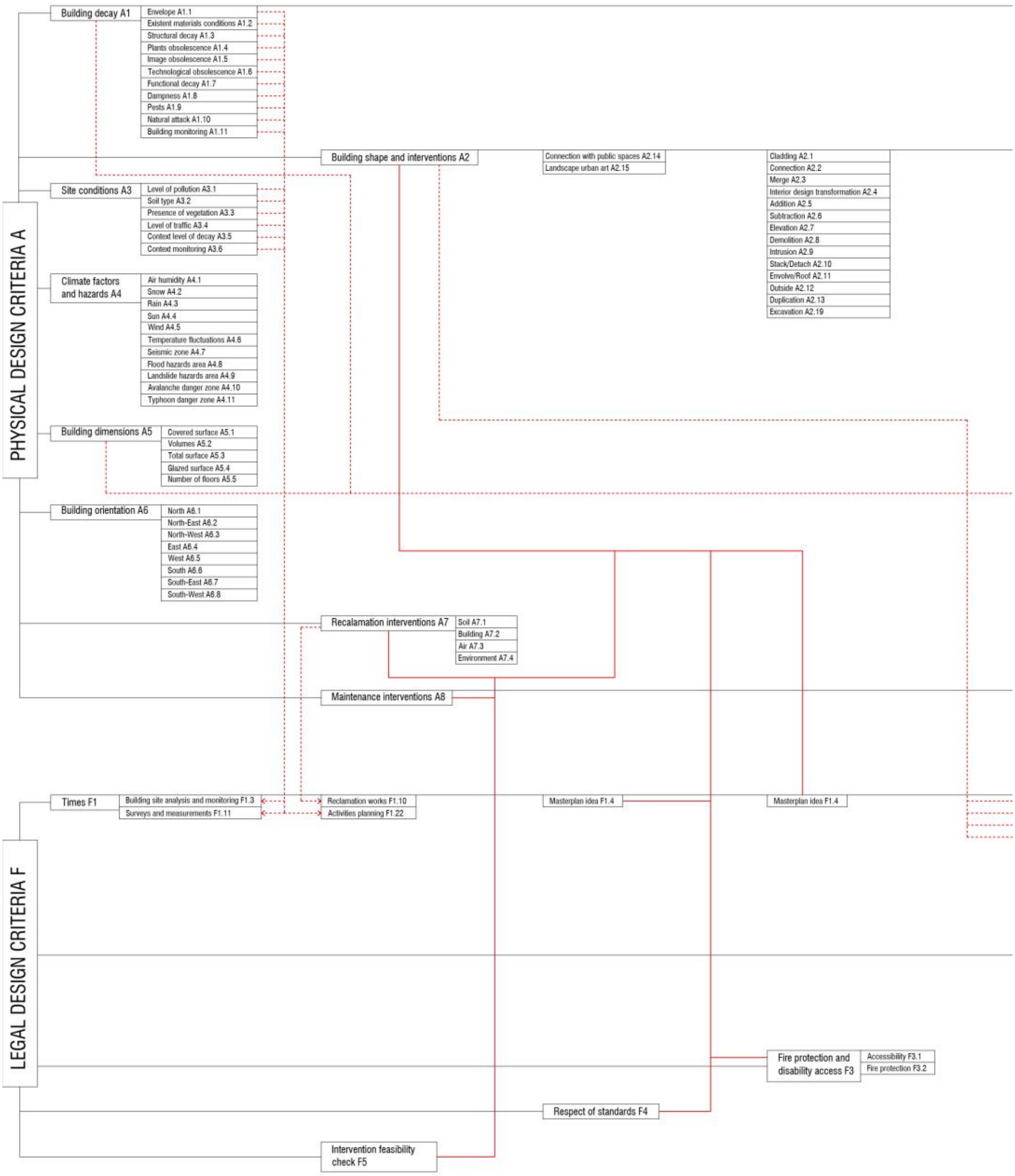
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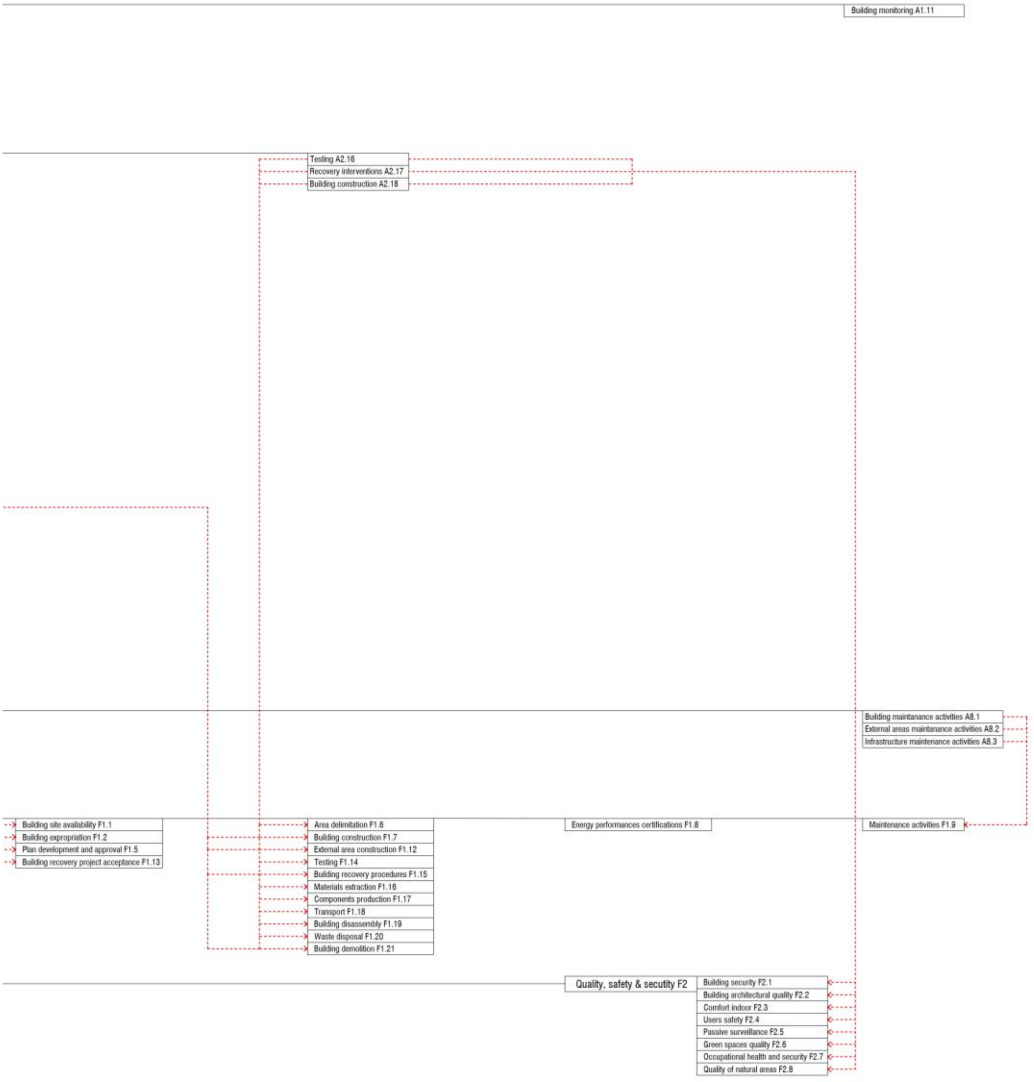
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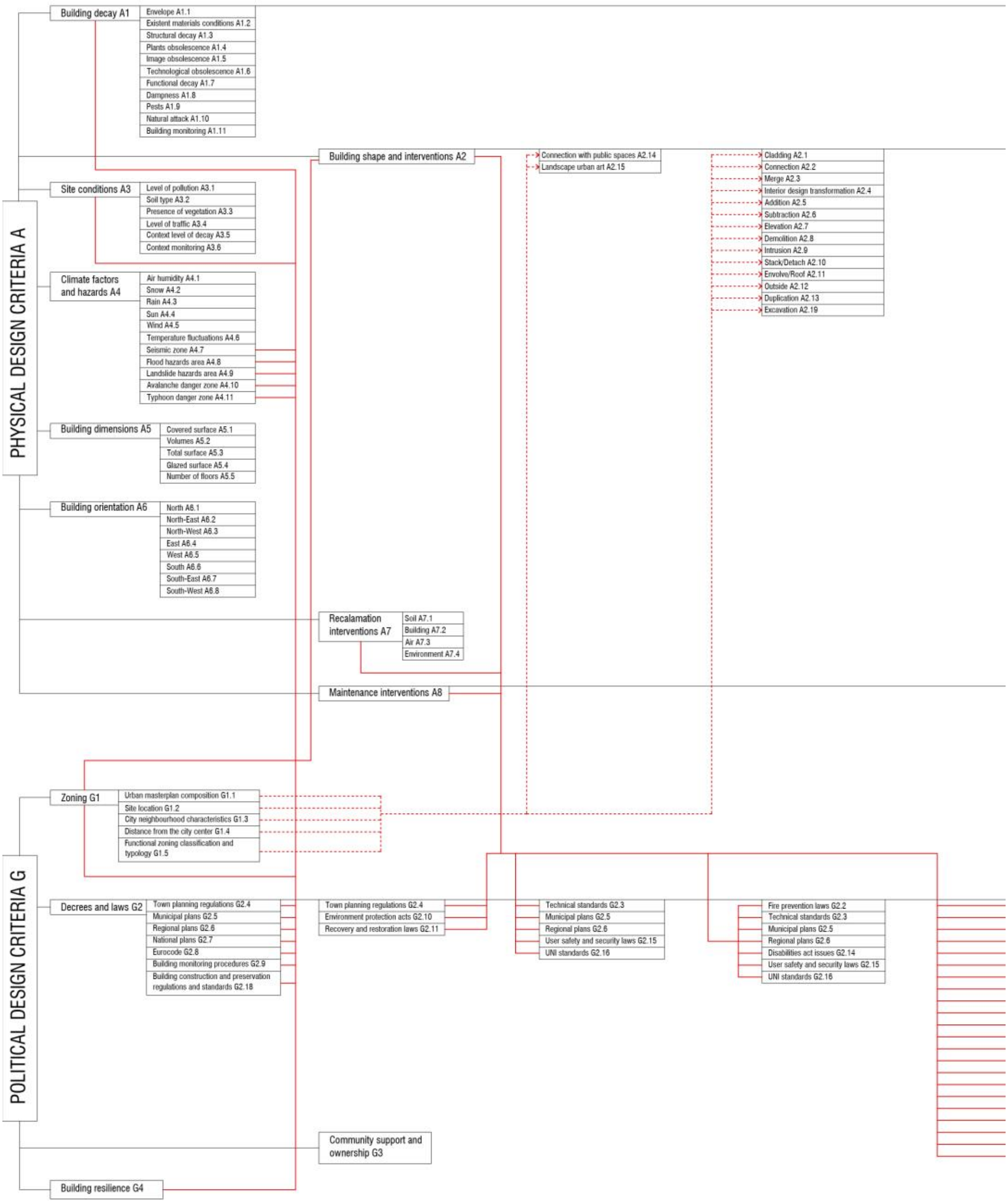
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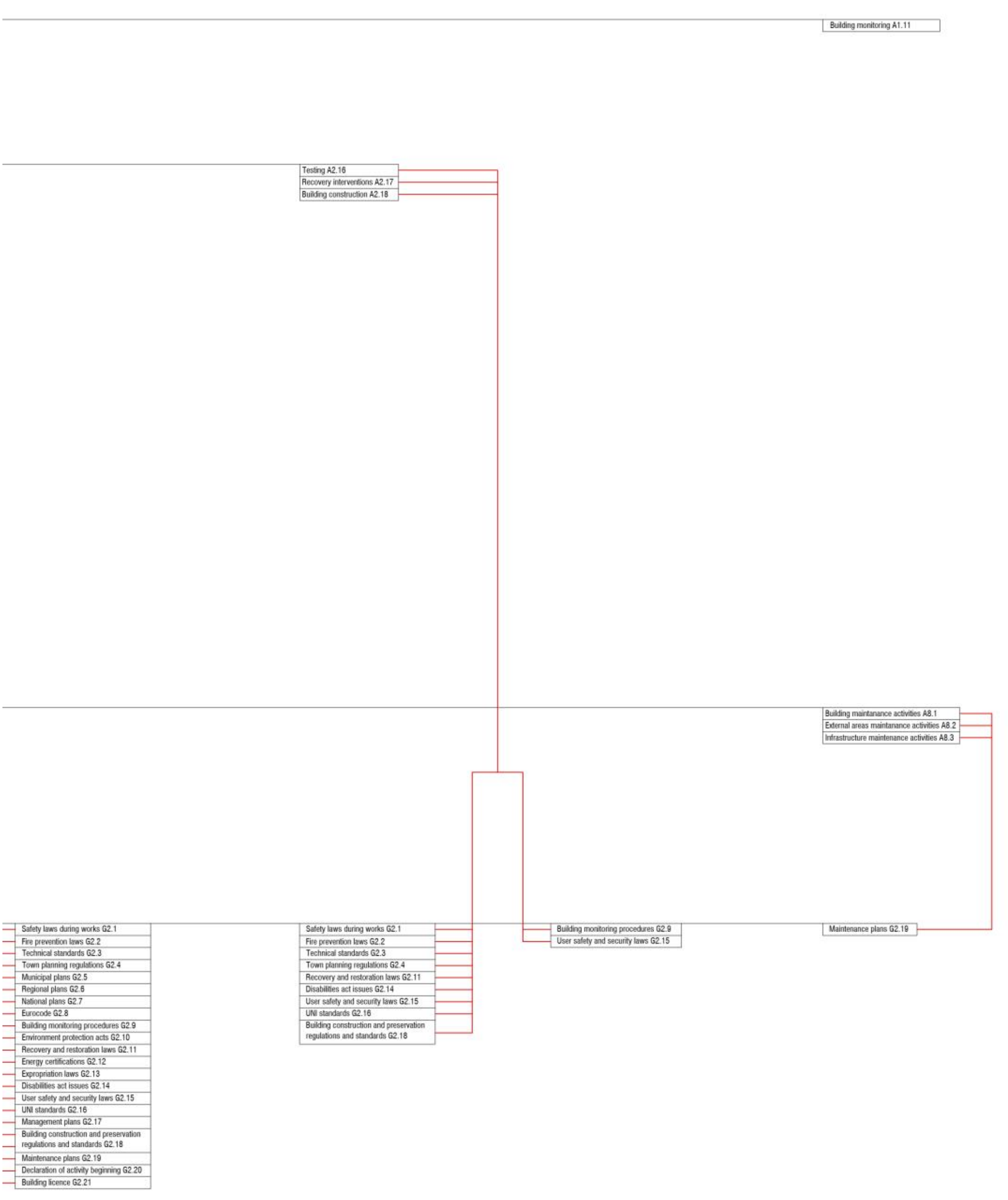
Regional plans G2.6
Disabilities act issues G2.14
User safety and security laws G2.15
UNI standards G2.16
Community support and ownership G3
Building resilience G4


Building monitoring A1.11
Testing A2.16
Recovery interventions A2.17
Building construction A2.18
Building maintanance activities A8.1
External areas maintanance activities A8.2
Infrastructure maintenance activities A8.3
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Disabilities act issues G2.14
User safety and security laws G2.15
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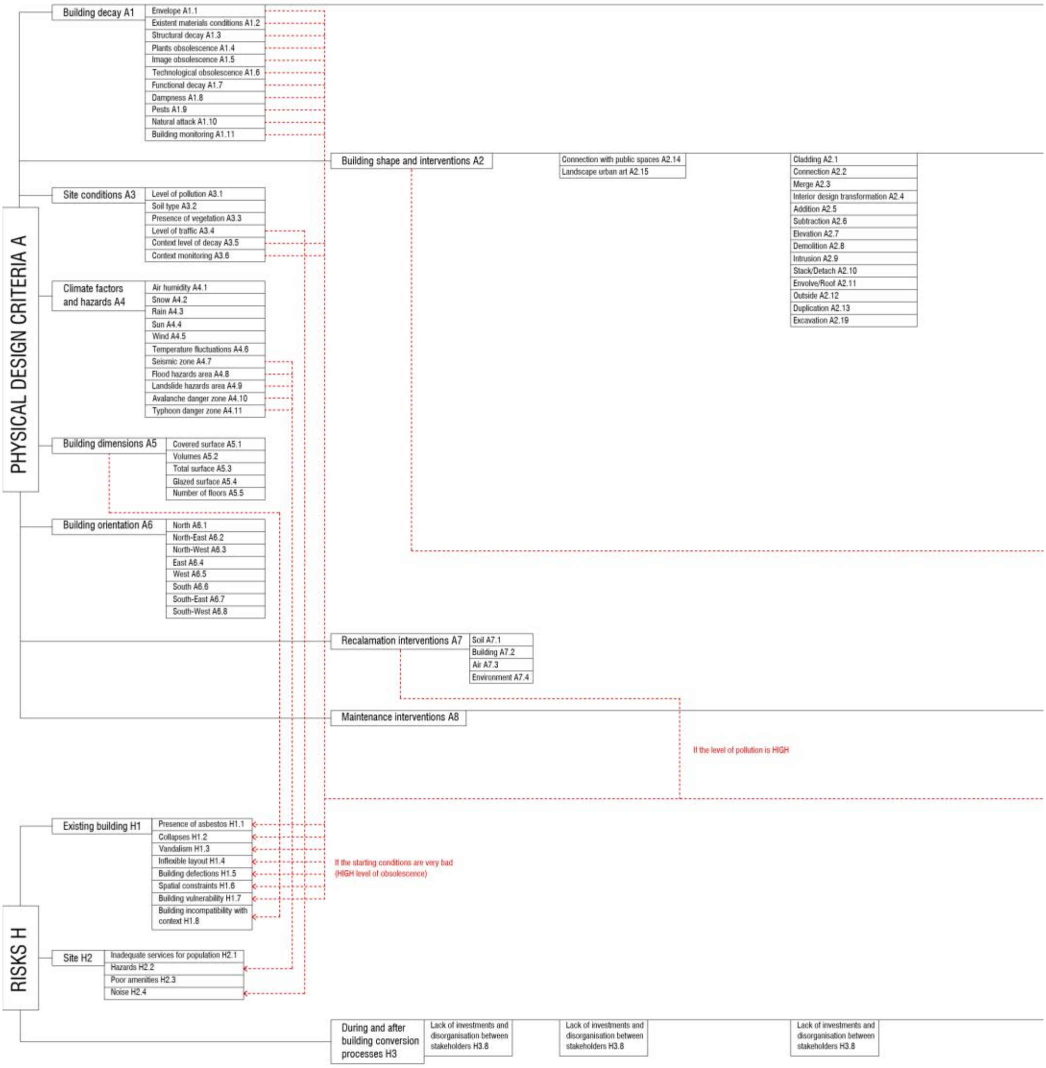
Building construction and preservation regulations and standards G2.18
Building monitoring procedures G2.9
User safety and security laws G2.15
Maintenance plans G2.19


PHYSICAL DESIGN CRITERIA A
Building decay A1
Envelope A1.1
Existent materials conditions A1.2
Structural decay A1.3
Plants obsolescence A1.4
Image obsolescence A1.5
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RISKS H
Existing building H1
Presence of asbestos H1.1
Collapses H1.2
Vandalism H1.3
Inflexible layout H1.4
Building defections H1.5
Spatial constraints H1.6
Building vulnerability H1.7
Building incompatibility with context H1.8
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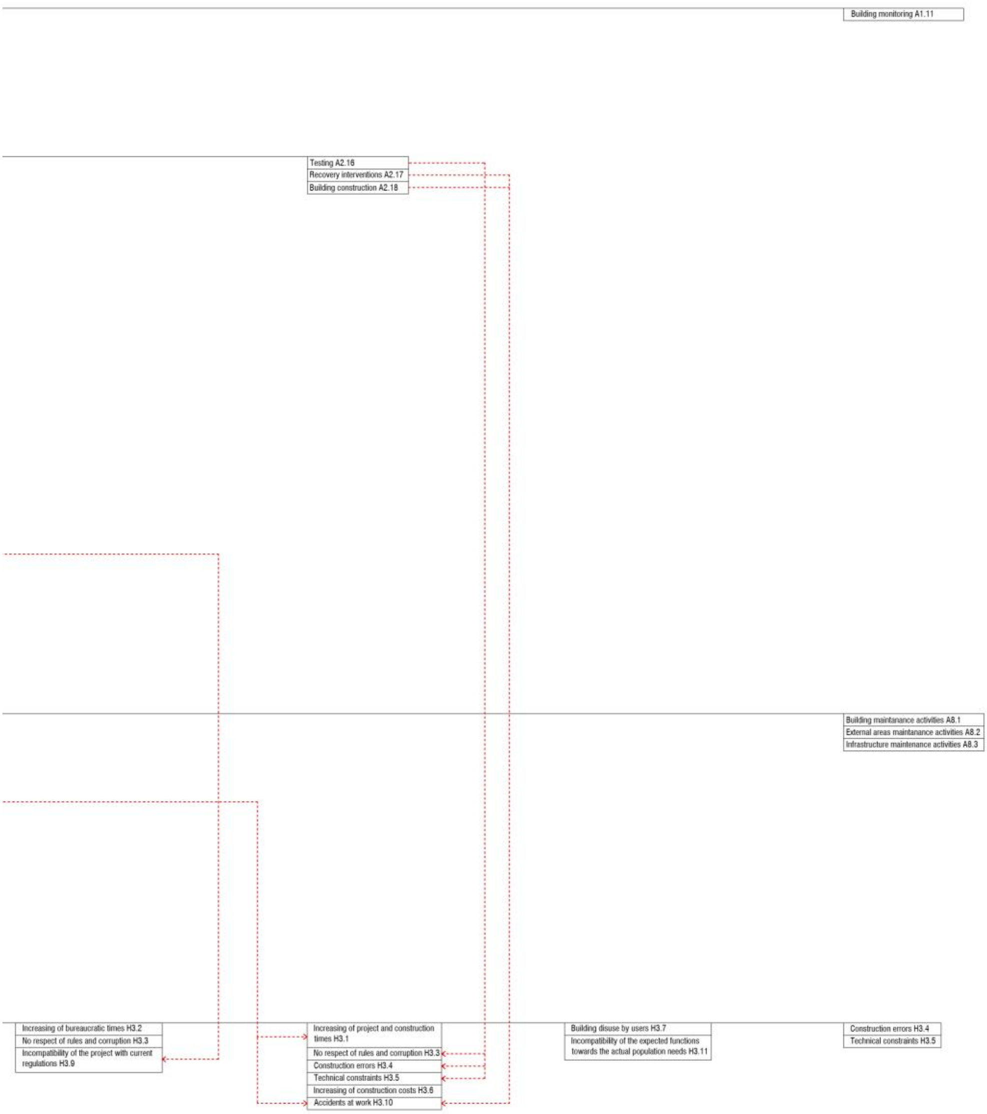
Site H2
Inadequate services for population H2.1
Hazards H2.2
Poor amenities H2.3
Noise H2.4
During and after building conversion processes H3
Lack of investments and disorganisation between stakeholders H3.8
Lack of investments and disorganisation between stakeholders H3.8
Lack of investments and disorganisation between stakeholders H3.8



Building monitoring A1.11
Testing A2.16
Recovery interventions A2.17
Building construction A2.18
Building maintanance activities A8.1
External areas maintanance activities A8.2
Infrastructure maintenance activities A8.3
Increasing of bureaucratic times H3.2
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Incompatibility of the project with current regulations H3.9
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No respect of rules and corruption H3.3
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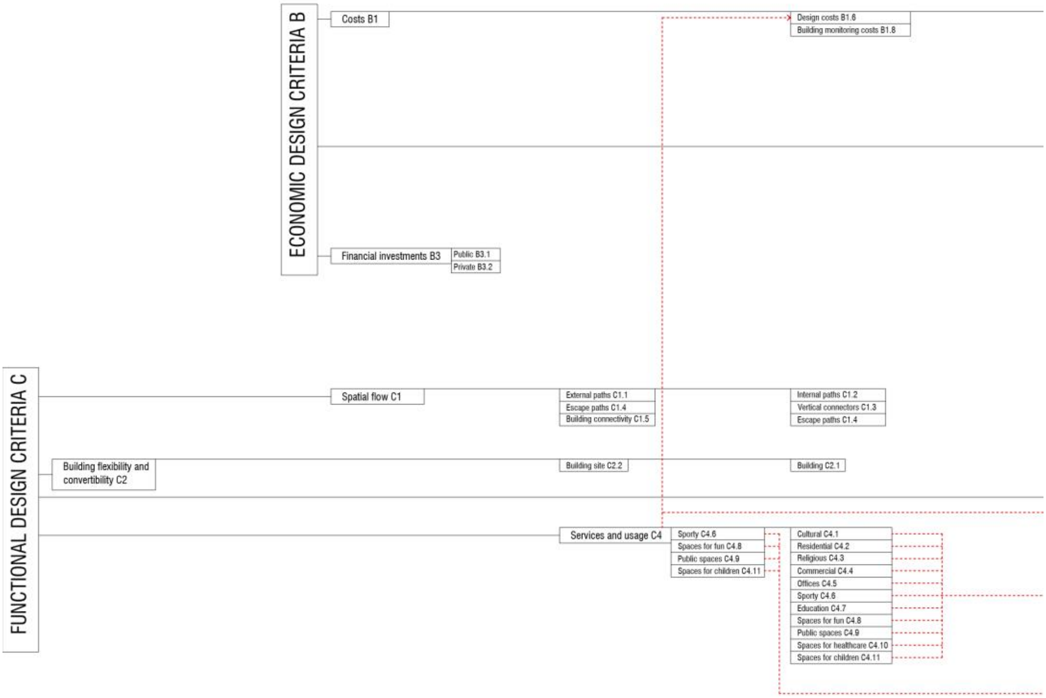
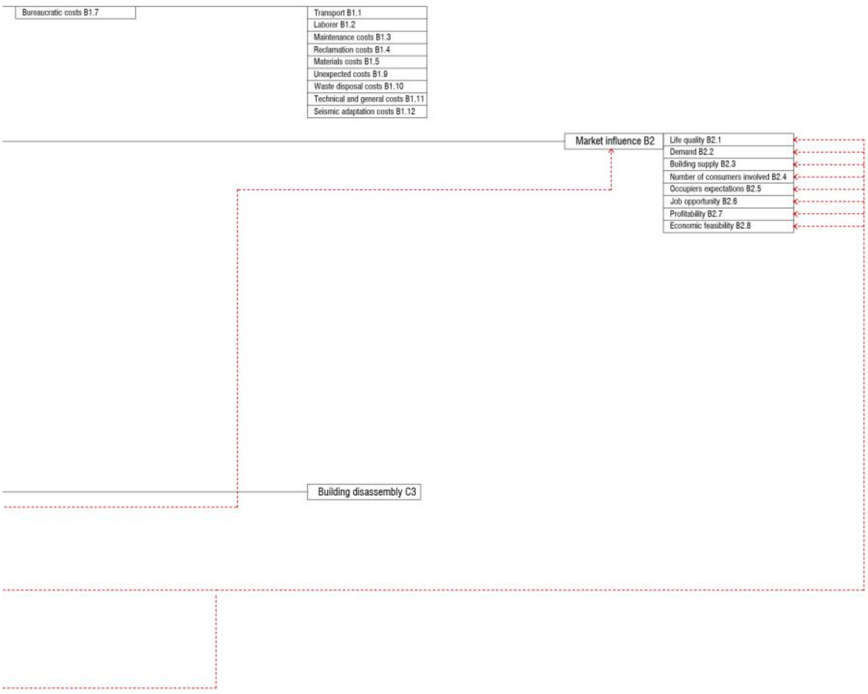
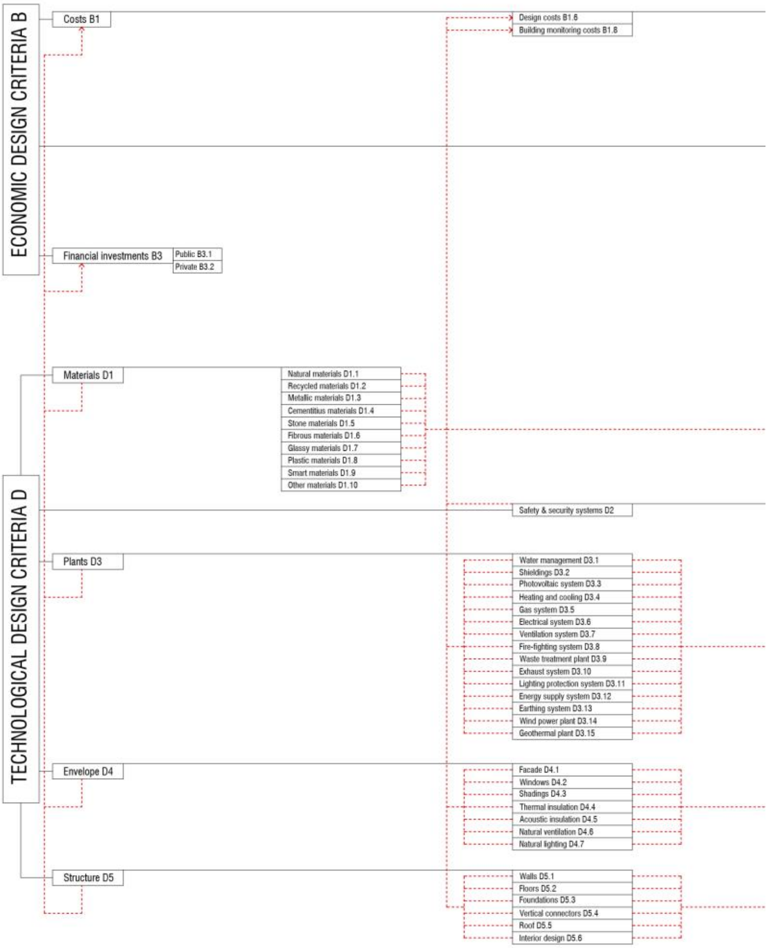
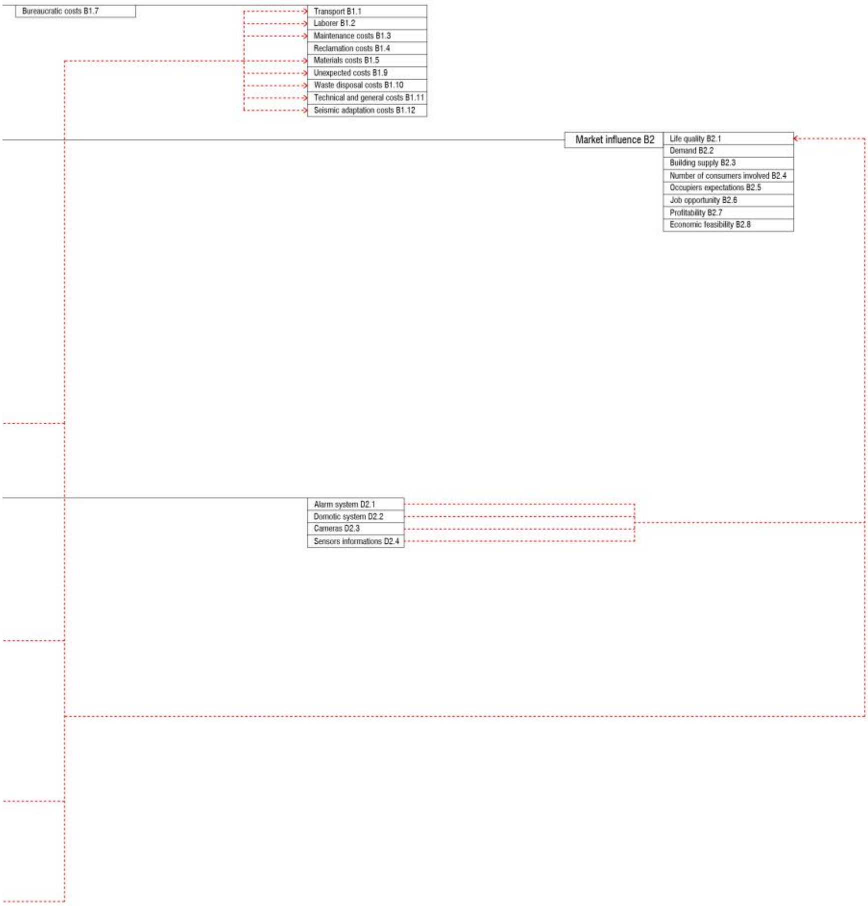
Technical constraints H3.5
Increasing of construction costs H3.6
Accidents at work H3.10
Building disuse by users H3.7
Incompatibility of the expected functions towards the actual population needs H3.11
Construction errors H3.4
Technical constraints H3.5


ECONOMIC DESIGN CRITERIA B
Costs B1
Design costs B1.6
Building monitoring costs B1.8
Financial investments B3
Public B3.1
Private B3.2
FUNCTIONAL DESIGN CRITERIA C
Spatial flow C1
External paths C1.1
Escape paths C1.4
Building connectivity C1.5
Internal paths C1.2
Vertical connectors C1.3
Escape paths C1.4
Building flexibility and convertibility C2
Building site C2.2
Building C2.1
Services and usage C4
Sporty C4.6
Spaces for fun C4.8
Public spaces C4.9
Spaces for children C4.11
Cultural C4.1
Residential C4.2
Religious C4.3
Commercial C4.4
Offices C4.5
Sporty C4.6
Education C4.7
Spaces for fun C4.8
Public spaces C4.9
Spaces for healthcare C4.10
Spaces for children C4.11


Bureaucratic costs B1.7
Transport B1.1
Laborer B1.2
Maintenance costs B1.3
Reclamation costs B1.4
Materials costs B1.5
Unexpected costs B1.9
Waste disposal costs B1.10
Technical and general costs B1.11
Seismic adaptation costs B1.12
Market influence B2
Life quality B2.1
Demand B2.2
Building supply B2.3
Number of consumers involved B2.4
Occupiers expectations B2.5
Job opportunity B2.6
Profitability B2.7
Economic feasibility B2.8
Building disassembly C3



ECONOMIC DESIGN CRITERIA B
Costs B1
Design costs B1.6
Building monitoring costs B1.8
Financial investments B3
Public B3.1
Private B3.2
TECHNOLOGICAL DESIGN CRITERIA D
Materials D1
Natural materials D1.1
Recycled materials D1.2
Metallic materials D1.3
Cementitius materials D1.4
Stone materials D1.5
Fibrous materials D1.6
Glassy materials D1.7
Plastic materials D1.8
Smart materials D1.9
Other materials D1.10
Safety & security systems D2
Plants D3
Water management D3.1
Shieldings D3.2
Photovoltaic system D3.3
Heating and cooling D3.4
Gas system D3.5
Electrical system D3.6
Ventilation system D3.7
Fire-fighting system D3.8
Waste treatment plant D3.9
Exhaust system D3.10
Lighting protection system D3.11
Energy supply system D3.12
Earthing system D3.13
Wind power plant D3.14
Geothermal plant D3.15
Envelope D4
Facade D4.1
Windows D4.2
Shadings D4.3
Thermal insulation D4.4
Acoustic insulation D4.5
Natural ventilation D4.6
Natural lighting D4.7
Structure D5
Walls D5.1
Floors D5.2
Foundations D5.3
Vertical connectors D5.4
Roof D5.5
Interior design D5.6



Bureaucratic costs B1.7
Transport B1.1
Laborer B1.2
Maintenance costs B1.3
Reclamation costs B1.4
Materials costs B1.5
Unexpected costs B1.9
Waste disposal costs B1.10
Technical and general costs B1.11
Seismic adaptation costs B1.12
Market influence B2
Life quality B2.1
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Occupiers expectations B2.5
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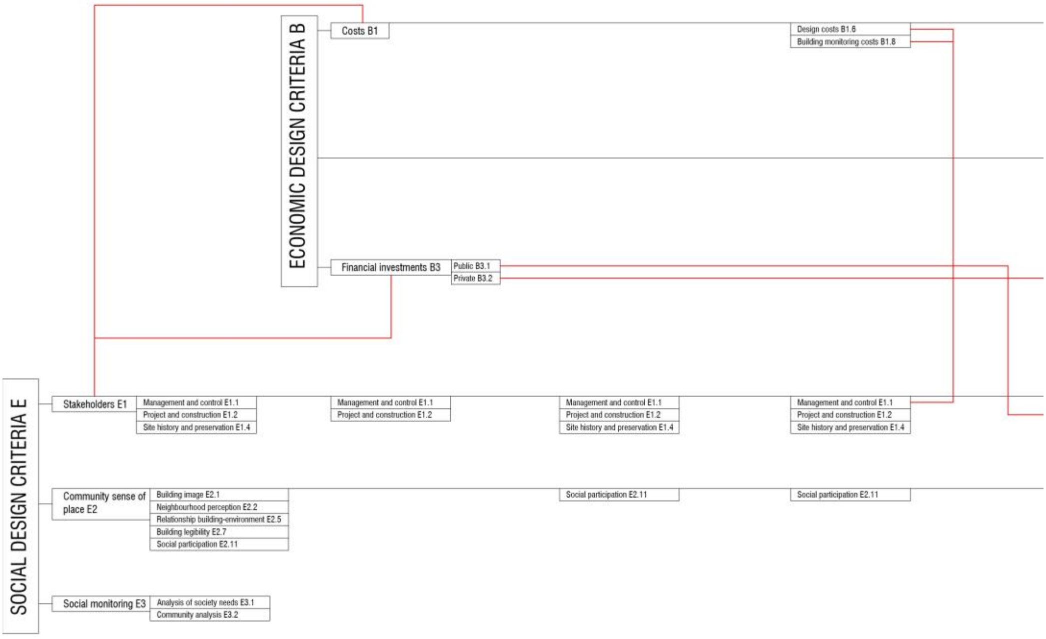
Profitability B2.7
Economic feasibility B2.8
Alarm system D2.1
Domotic system D2.2
Cameras D2.3
Sensors informations D2.4



ECONOMIC DESIGN CRITERIA B
Costs B1
Design costs B1.6
Building monitoring costs B1.8
Financial investments B3
Public B3.1
Private B3.2
SOCIAL DESIGN CRITERIA E
Stakeholders E1
Management and control E1.1
Project and construction E1.2
Site history and preservation E1.4
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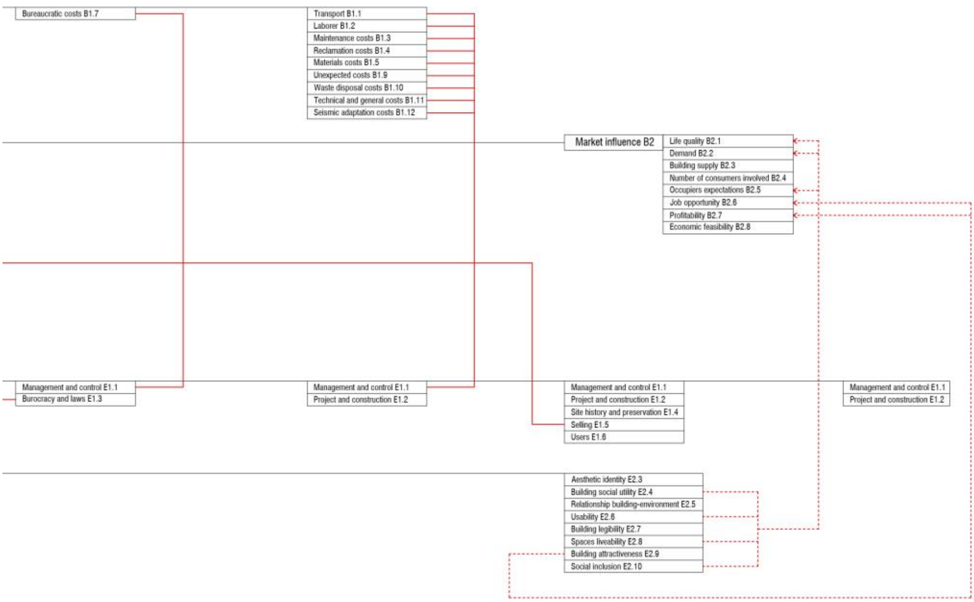
Neighbourhood perception E2.2
Relationship building-environment E2.5
Building legibility E2.7
Social participation E2.11
Social monitoring E3
Analysis of society needs E3.1
Community analysis E3.2


Bureaucratic costs B1.7
Transport B1.1
Laborer B1.2
Maintenance costs B1.3
Reclamation costs B1.4
Materials costs B1.5
Unexpected costs B1.9
Waste disposal costs B1.10
Technical and general costs B1.11
Seismic adaptation costs B1.12
Market influence B2
Life quality B2.1
Demand B2.2
Building supply B2.3
Number of consumers involved B2.4
Occupiers expectations B2.5
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Profitability B2.7
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Management and control E1.1
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Aesthetic identity E2.3
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Relationship building-environment E2.5
Usability E2.6
Building legibility E2.7
Spaces liveability E2.8
Building attractiveness E2.9
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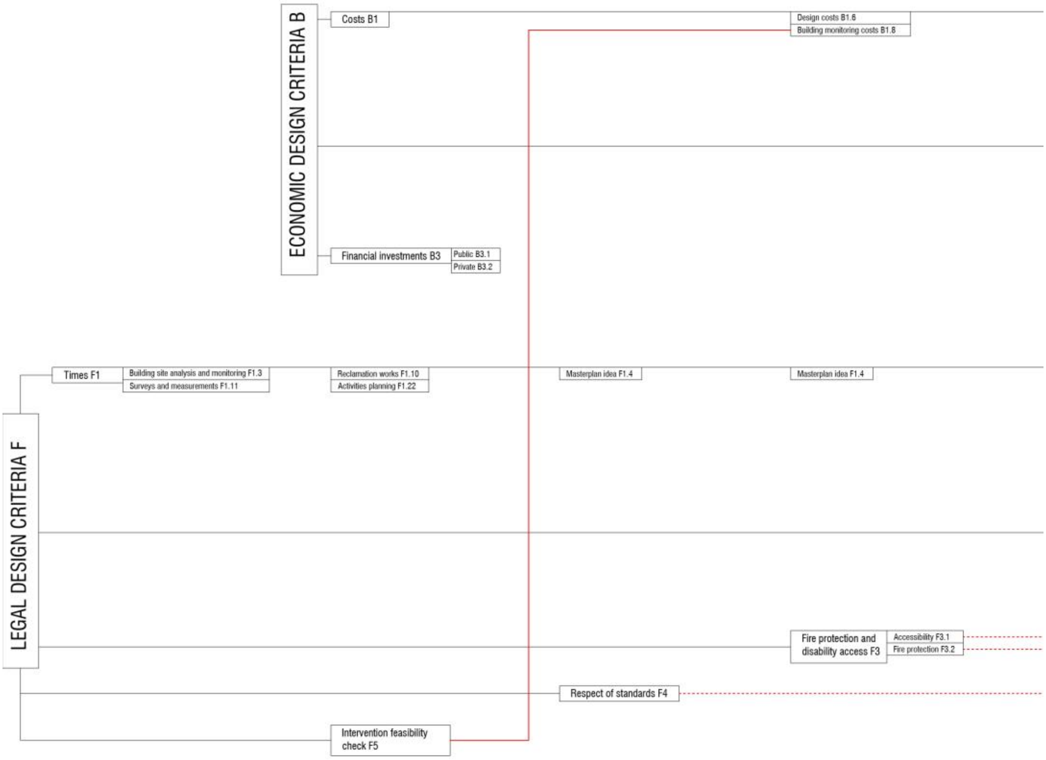
ECONOMIC DESIGN CRITERIA B
Costs B1
Design costs B1.6
Building monitoring costs B1.8
Financial investments B3
Public B3.1
Private B3.2
LEGAL DESIGN CRITERIA F
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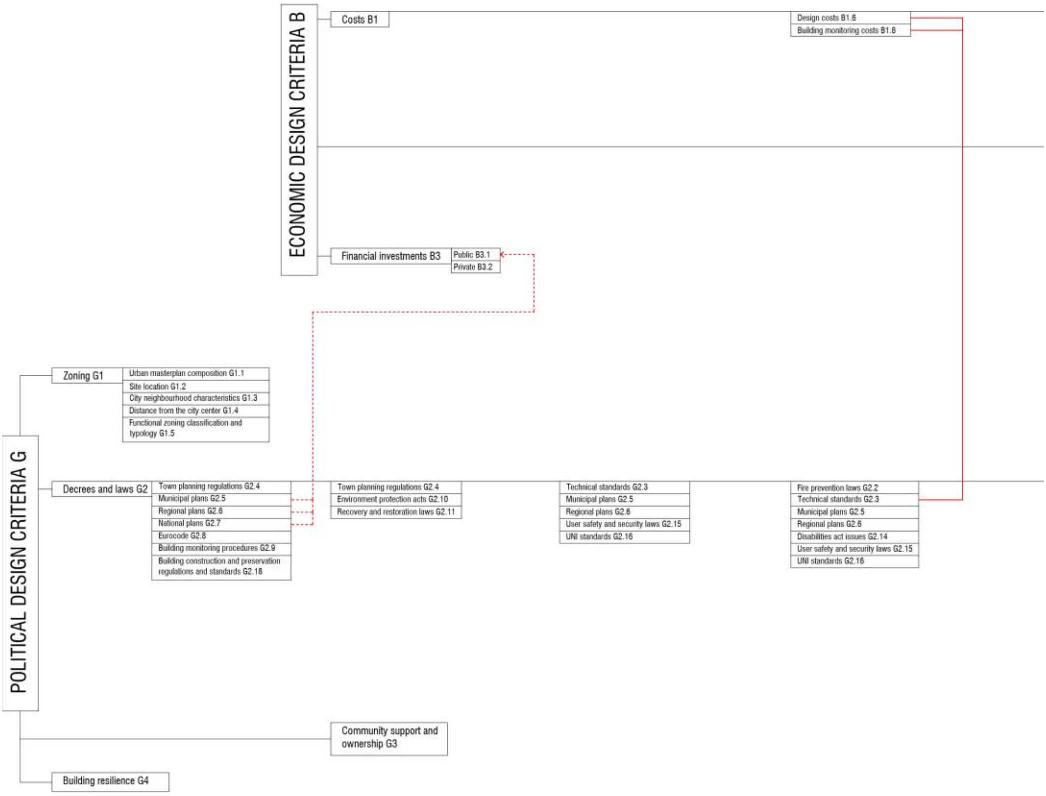
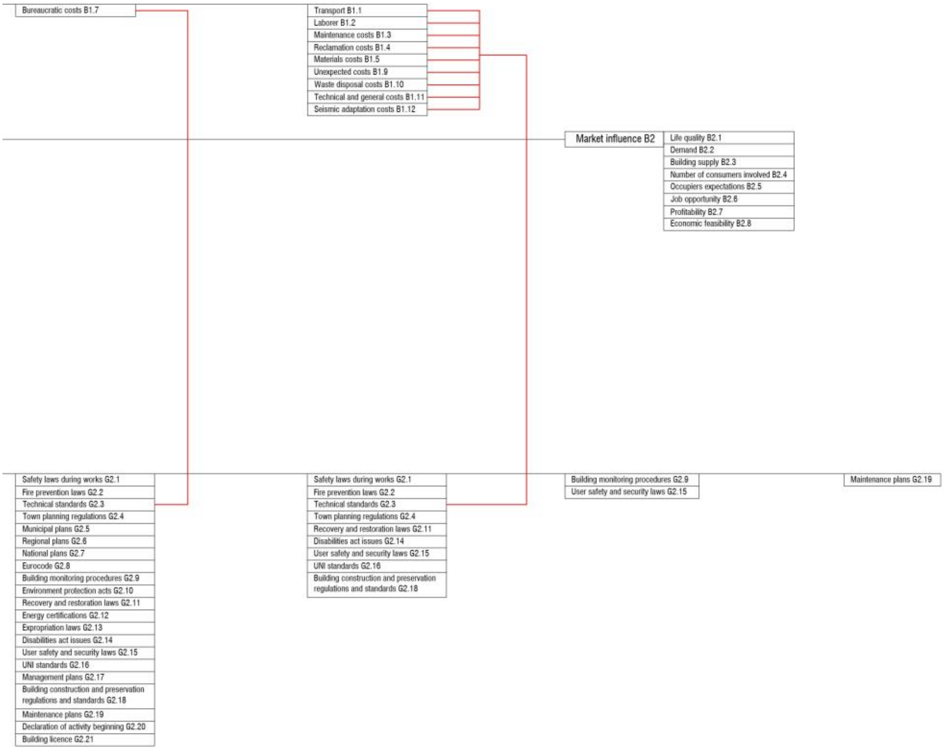
Reclamation works F1.10
Activities planning F1.22
Masterplan idea F1.4
Masterplan idea F1.4
Fire protection and disability access F3
Accessibility F3.1
Fire protection F3.2
Respect of standards F4
Intervention feasibility check F5

Bureaucratic costs B1.7
Transport B1.1
Laborer B1.2
Maintenance costs B1.3
Reclamation costs B1.4
Materials costs B1.5
Unexpected costs B1.9
Waste disposal costs B1.10
Technical and general costs B1.11
Seismic adaptation costs B1.12
Market influence B2
Life quality B2.1
Demand B2.2
Building supply B2.3
Number of consumers involved B2.4
Occupiers expectations B2.5
Job opportunity B2.6
Profitability B2.7
Economic feasibility B2.8
Building site availability F1.1
Building expropriation F1.2
Plan development and approval F1.5
Building recovery project acceptance F1.13
Area delimitation F1.6
Building construction F1.7
External area construction F1.12
Testing F1.14
Building recovery procedures F1.15
Materials extraction F1.16
Components production F1.17
Transport F1.18
Building disassembly F1.19
Waste disposal F1.20
Building demolition F1.21
Energy performances certifications F1.8
Maintenance activities F1.9
Quality, safety & secutity F2
Building security F2.1
Building architectural quality F2.2
Comfort indoor F2.3
Users safety F2.4
Passive surveillance F2.5
Green spaces quality F2.6
Occupational health and security F2.7
Quality of natural areas F2.8



ECONOMIC DESIGN CRITERIA B
Costs B1
Design costs B1.6
Building monitoring costs B1.8
Financial investments B3
Public B3.1
Private B3.2
POLITICAL DESIGN CRITERIA G
Zoning G1
Urban masterplan composition G1.1
Site location G1.2
City neighbourhood characteristics G1.3
Distance from the city center G1.4
Functional zoning classification and typology G1.5
Decrees and laws G2
Town planning regulations G2.4
Municipal plans G2.5
Regional plans G2.6
National plans G2.7
Eurocode G2.8
Building monitoring procedures G2.9
Building construction and preservation regulations and standards G2.18
Town planning regulations G2.4
Environment protection acts G2.10
Recovery and restoration laws G2.11
Technical standards G2.3
Municipal plans G2.5
Regional plans G2.6
User safety and security laws G2.15
UNI standards G2.16
Fire prevention laws G2.2
Technical standards G2.3
Municipal plans G2.5
Regional plans G2.6
Disabilities act issues G2.14
User safety and security laws G2.15
UNI standards G2.16
Community support and ownership G3
Building resilience G4



Bureaucratic costs B1.7
Transport B1.1
Laborer B1.2
Maintenance costs B1.3
Reclamation costs B1.4
Materials costs B1.5
Unexpected costs B1.9
Waste disposal costs B1.10
Technical and general costs B1.11
Seismic adaptation costs B1.12
Market influence B2
Life quality B2.1
Demand B2.2
Building supply B2.3
Number of consumers involved B2.4
Occupiers expectations B2.5
Job opportunity B2.6
Profitability B2.7
Economic feasibility B2.8
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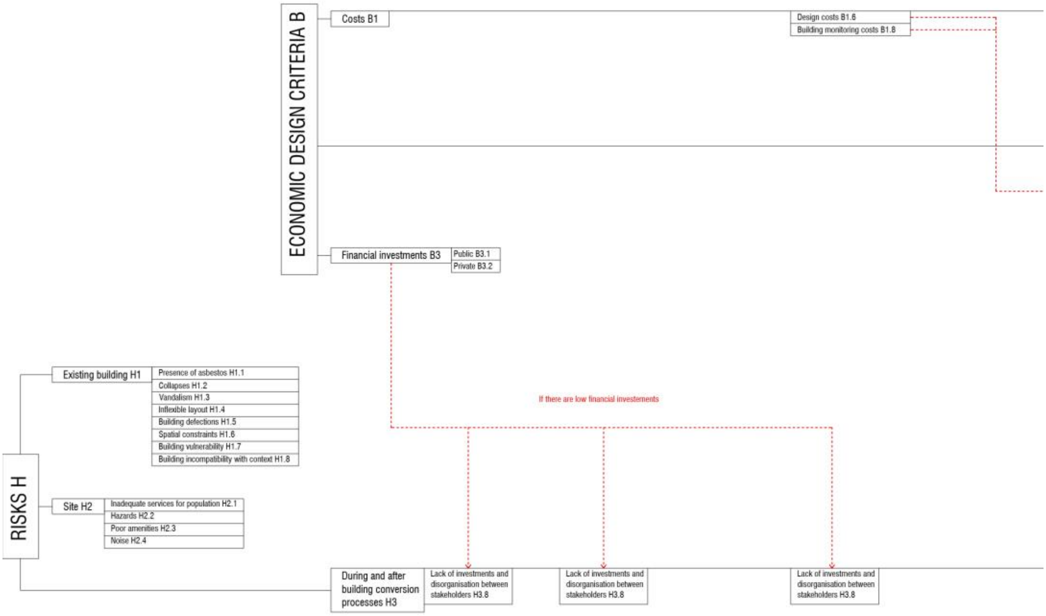
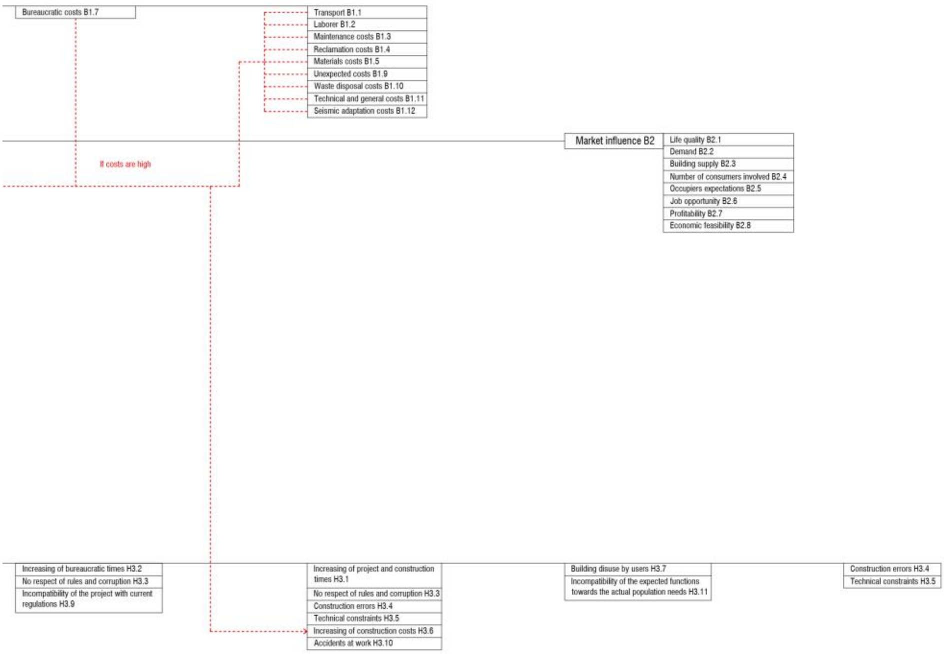
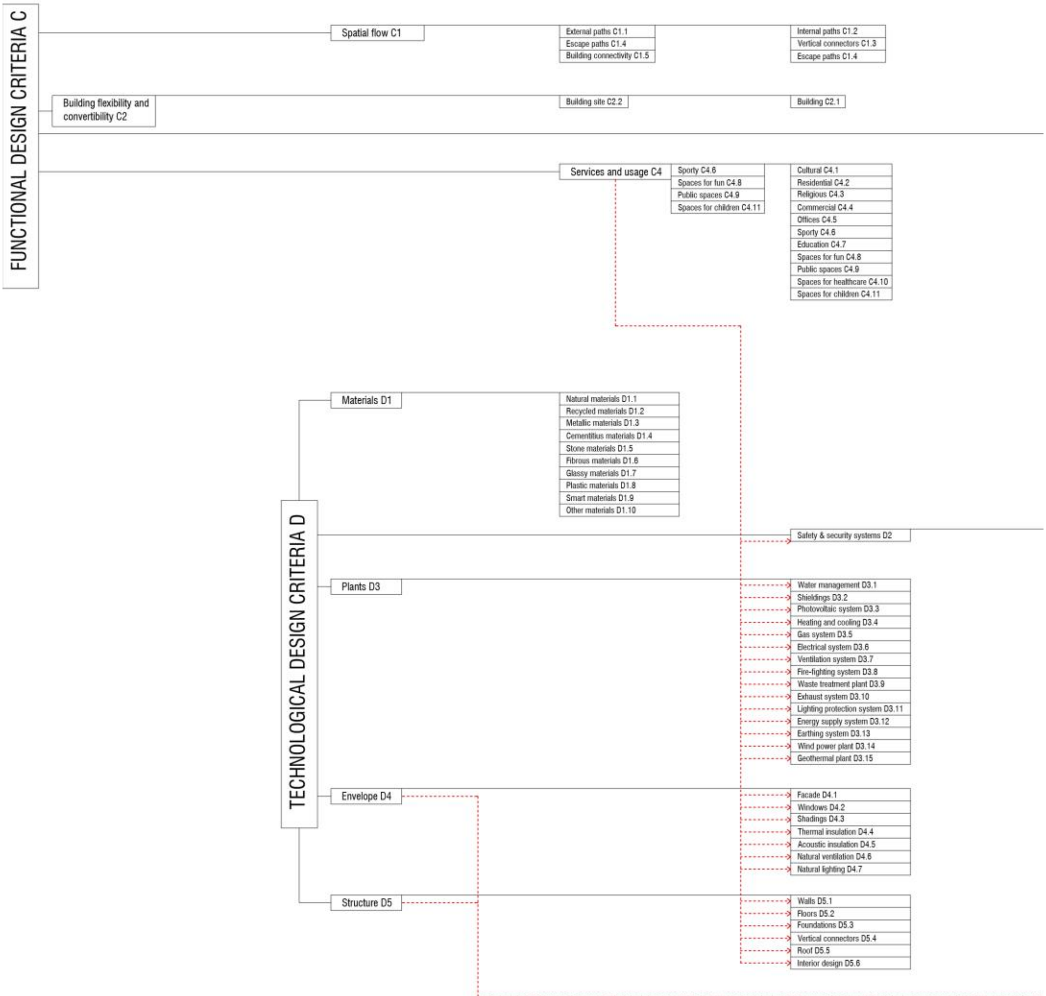
Maintenance plans G2.19

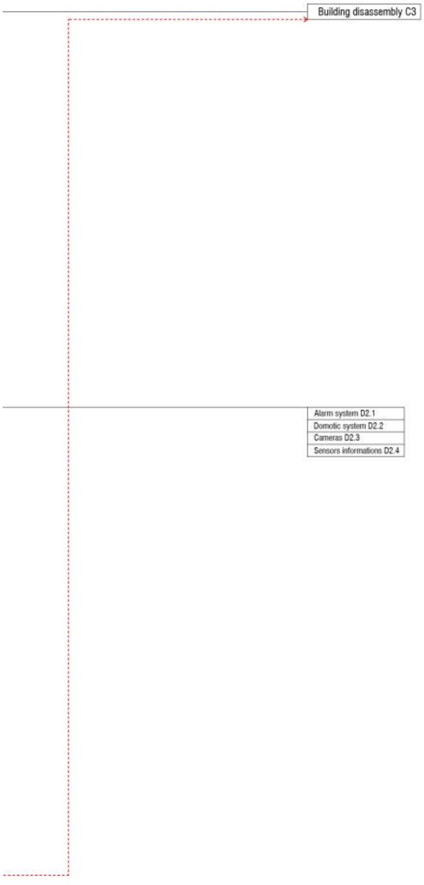

ECONOMIC DESIGN CRITERIA B
Costs B1
Design costs B1.6
Building monitoring costs B1.8
Financial investments B3
Public B3.1
Private B3.2
If there are low financial investements
RISKS H
Existing building H1
Presence of asbestos H1.1
Collapses H1.2
Vandalism H1.3
Inflexible layout H1.4
Building defections H1.5
Spatial constraints H1.6
Building vulnerability H1.7
Building incompatibility with context H1.8
Site H2
Inadequate services for population H2.1
Hazards H2.2
Poor amenities H2.3
Noise H2.4
During and after building conversion processes H3
Lack of investments and disorganisation between stakeholders H3.8
Lack of investments and disorganisation between stakeholders H3.8
Lack of investments and disorganisation between stakeholders H3.8

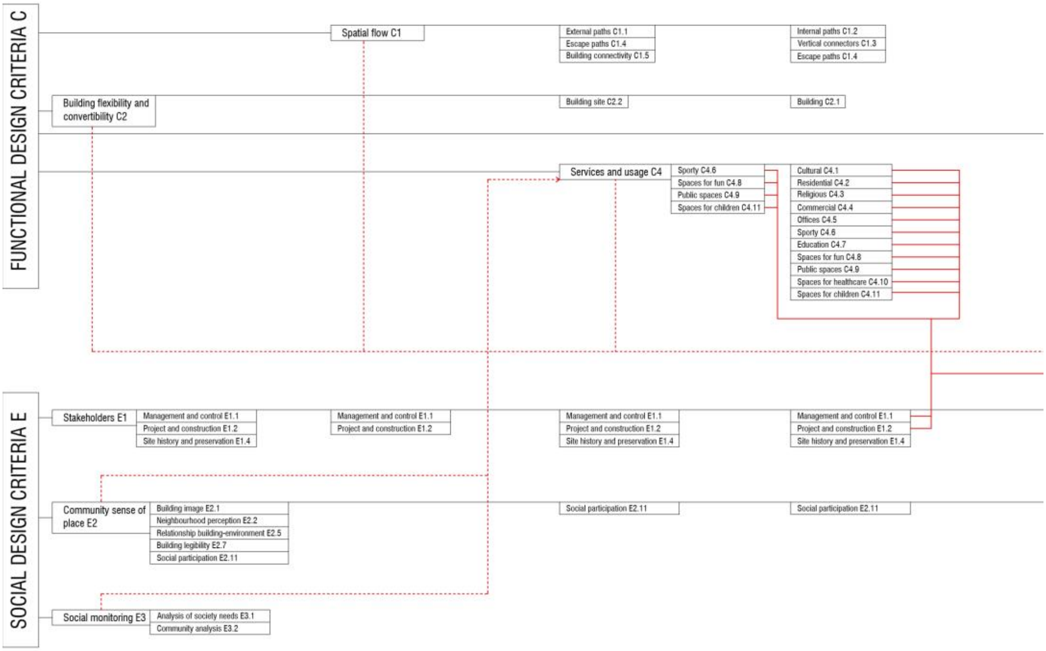


Bureaucratic costs B1.7
Transport B1.1
Laborer B1.2
Maintenance costs B1.3
Reclamation costs B1.4
Materials costs B1.5
Unexpected costs B1.9
Waste disposal costs B1.10
Technical and general costs B1.11
Seismic adaptation costs B1.12
Market influence B2
Life quality B2.1
Demand B2.2
Building supply B2.3
Number of consumers involved B2.4
Occupiers expectations B2.5
Job opportunity B2.6
Profitability B2.7
Economic feasibility B2.8
If costs are high
Increasing of bureaucratic times H3.2
No respect of rules and corruption H3.3
Incompatibility of the project with current regulations H3.9
Increasing of project and construction times H3.1
No respect of rules and corruption H3.3
Construction errors H3.4
Technical constraints H3.5
Increasing of construction costs H3.6
Accidents at work H3.10
Building disuse by users H3.7
Incompatibility of the expected functions towards the actual population needs H3.11
Construction errors H3.4
Technical constraints H3.5



FUNCTIONAL DESIGN CRITERIA C
Spatial flow C1
External paths C1.1
Escape paths C1.4
Building connectivity C1.5
Internal paths C1.2
Vertical connectors C1.3
Escape paths C1.4
Building flexibility and convertibility C2
Building site C2.2
Building C2.1
Services and usage C4
Sporty C4.6
Spaces for fun C4.8
Public spaces C4.9
Spaces for children C4.11
Cultural C4.1
Residential C4.2
Religious C4.3
Commercial C4.4
Offices C4.5
Sporty C4.6
Education C4.7
Spaces for fun C4.8
Public spaces C4.9
Spaces for healthcare C4.10
Spaces for children C4.11
TECHNOLOGICAL DESIGN CRITERIA D
Materials D1
Natural materials D1.1
Recycled materials D1.2
Metallic materials D1.3
Cementitius materials D1.4
Stone materials D1.5
Fibrous materials D1.6
Glassy materials D1.7
Plastic materials D1.8
Smart materials D1.9
Other materials D1.10
Safety & security systems D2
Plants D3
Water management D3.1
Shieldings D3.2
Photovoltaic system D3.3
Heating and cooling D3.4
Gas system D3.5
Electrical system D3.6
Ventilation system D3.7
Fire-fighting system D3.8
Waste treatment plant D3.9
Exhaust system D3.10
Lighting protection system D3.11
Energy supply system D3.12
Earthing system D3.13
Wind power plant D3.14
Geothermal plant D3.15
Envelope D4
Facade D4.1
Windows D4.2
Shadings D4.3
Thermal insulation D4.4
Acoustic insulation D4.5
Natural ventilation D4.6
Natural lighting D4.7
Structure D5
Walls D5.1
Floors D5.2
Foundations D5.3
Vertical connectors D5.4
Roof D5.5
Interior design D5.6


Building disassembly C3
Alarm system D2.1
Domotic system D2.2
Cameras D2.3
Sensors informations D2.4


FUNCTIONAL DESIGN CRITERIA C
Spatial flow C1
External paths C1.1
Escape paths C1.4
Building connectivity C1.5
Internal paths C1.2
Vertical connectors C1.3
Escape paths C1.4
Building flexibility and convertibility C2
Building site C2.2
Building C2.1
Services and usage C4
Sporty C4.6
Spaces for fun C4.8
Public spaces C4.9
Spaces for children C4.11
Cultural C4.1
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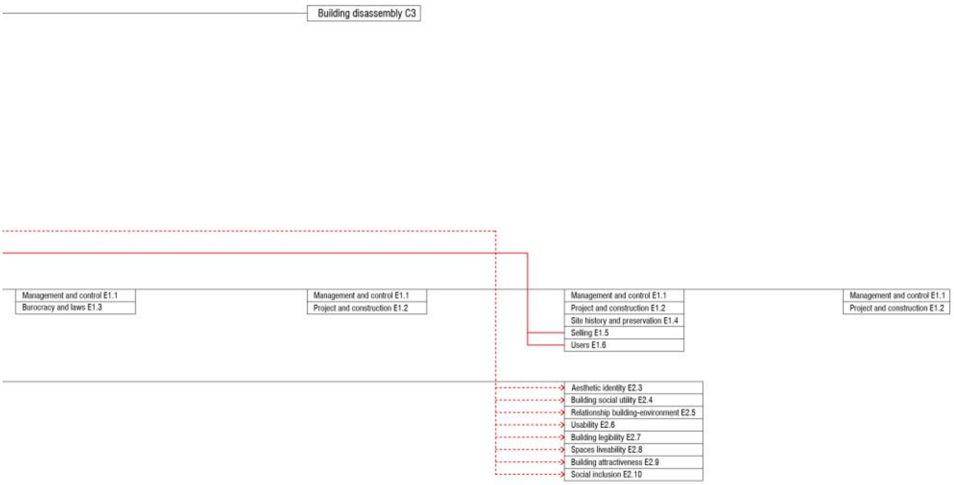
Offices C4.5
Sporty C4.6
Education C4.7
Spaces for fun C4.8
Public spaces C4.9
Spaces for healthcare C4.10
Spaces for children C4.11
SOCIAL DESIGN CRITERIA E
Stakeholders E1
Management and control E1.1
Project and construction E1.2
Site history and preservation E1.4
Management and control E1.1
Project and construction E1.2
Management and control E1.1
Project and construction E1.2
Site history and preservation E1.4
Management and control E1.1
Project and construction E1.2
Site history and preservation E1.4
Community sense of place E2
Building image E2.1
Neighbourhood perception E2.2
Relationship building-environment E2.5
Building legibility E2.7
Social participation E2.11
Social participation E2.11
Social participation E2.11
Social monitoring E3
Analysis of society needs E3.1
Community analysis E3.2


Building disassembly C3
Management and control E1.1
Burocracy and laws E1.3
Management and control E1.1
Project and construction E1.2
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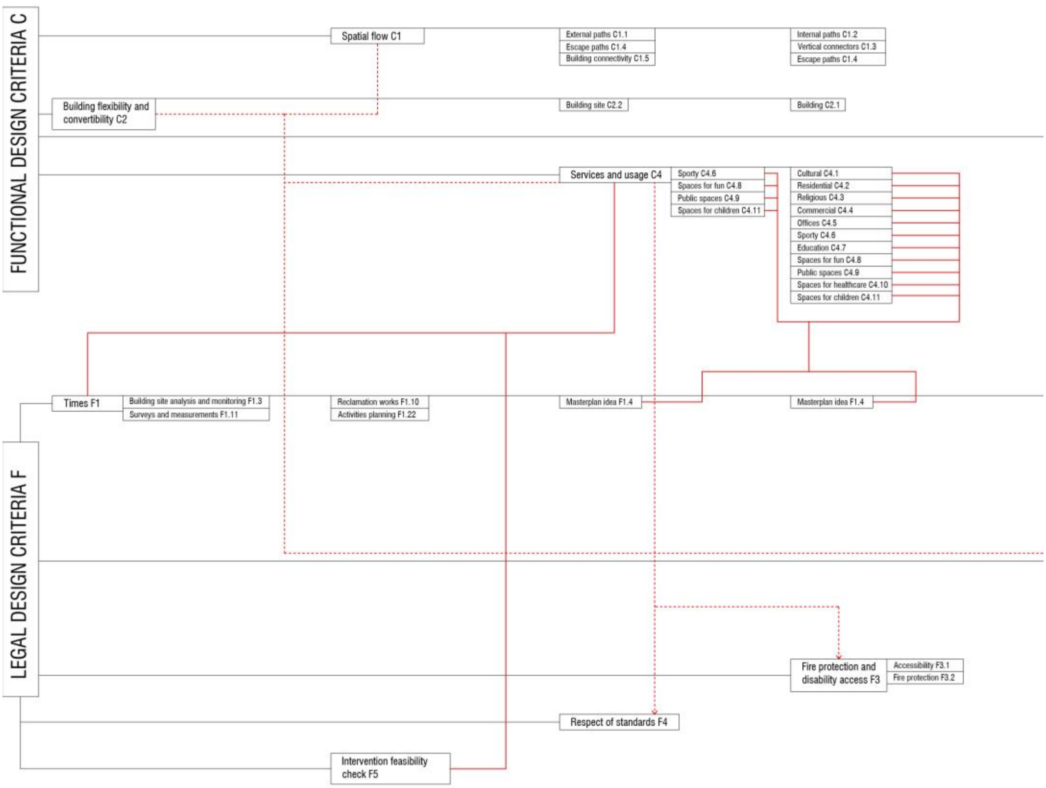
Project and construction E1.2
Site history and preservation E1.4
Selling E1.5
Users E1.6
Management and control E1.1
Project and construction E1.2
Aesthetic identity E2.3
Building social utility E2.4
Relationship building-environment E2.5
Usability E2.6
Building legibility E2.7
Spaces liveability E2.8
Building attractiveness E2.9
Social inclusion E2.10



FUNCTIONAL DESIGN CRITERIA C
Spatial flow C1
External paths C1.1
Escape paths C1.4
Building connectivity C1.5
Internal paths C1.2
Vertical connectors C1.3
Escape paths C1.4
Building flexibility and convertibility C2
Building site C2.2
Building C2.1
Services and usage C4
Sporty C4.6
Spaces for fun C4.8
Public spaces C4.9
Spaces for children C4.11
Cultural C4.1
Residential C4.2
Religious C4.3
Commercial C4.4
Offices C4.5
Sporty C4.6
Education C4.7
Spaces for fun C4.8
Public spaces C4.9
Spaces for healthcare C4.10
Spaces for children C4.11
LEGAL DESIGN CRITERIA F
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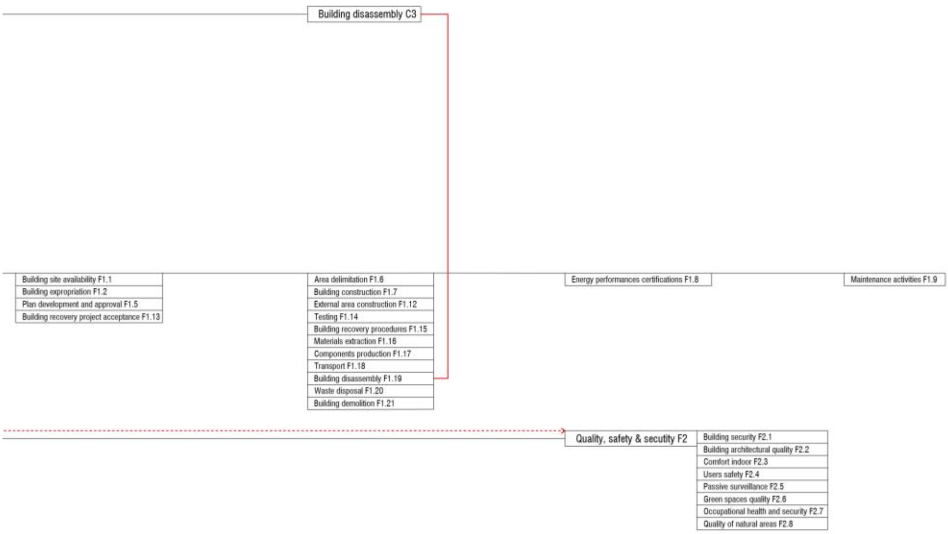
Masterplan idea F1.4
Masterplan idea F1.4
Fire protection and disability access F3
Accessibility F3.1
Fire protection F3.2
Respect of standards F4
Intervention feasibility check F5


Building disassembly C3
Building site availability F1.1
Building expropriation F1.2
Plan development and approval F1.5
Building recovery project acceptance F1.13
Area delimitation F1.6
Building construction F1.7
External area construction F1.12
Testing F1.14
Building recovery procedures F1.15
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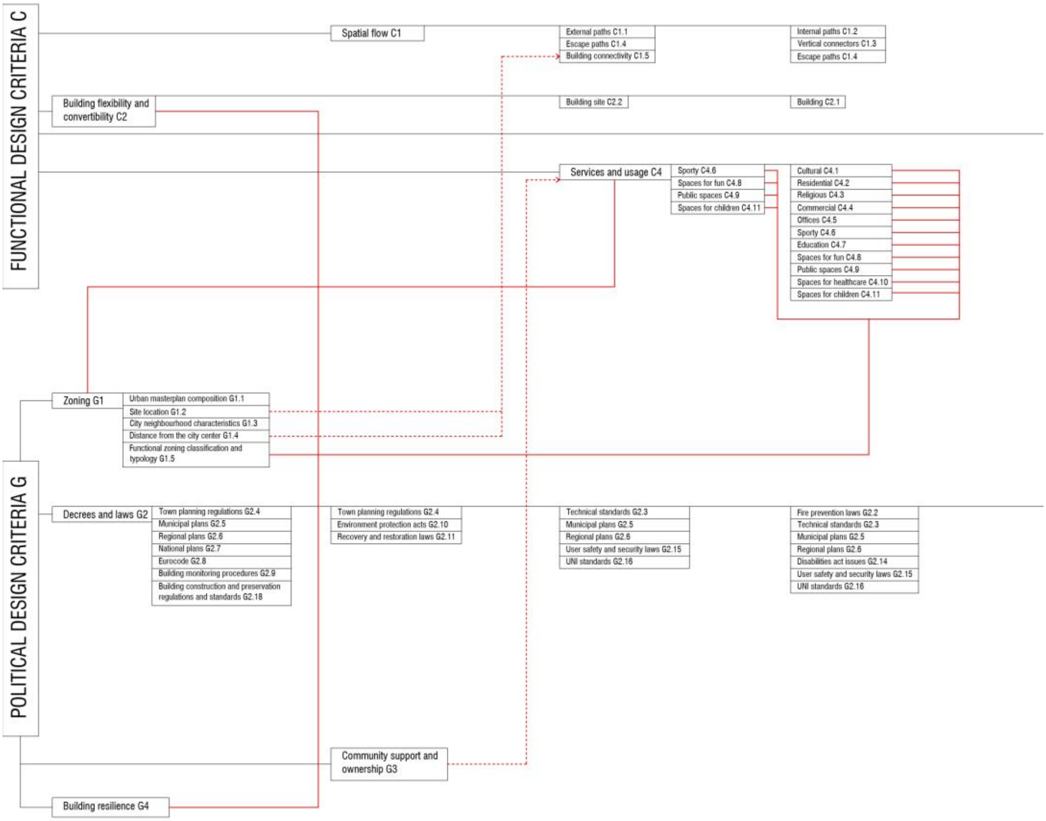
Transport F1.18
Building disassembly F1.19
Waste disposal F1.20
Building demolition F1.21
Energy performances certifications F1.8
Maintenance activities F1.9
Quality, safety & secutity F2
Building security F2.1
Building architectural quality F2.2
Comfort indoor F2.3
Users safety F2.4
Passive surveillance F2.5
Green spaces quality F2.6
Occupational health and security F2.7
Quality of natural areas F2.8


FUNCTIONAL DESIGN CRITERIA C
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Internal paths C1.2
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Spaces for children C4.11
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City neighbourhood characteristics G1.3
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Recovery and restoration laws G2.11
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Municipal plans G2.5
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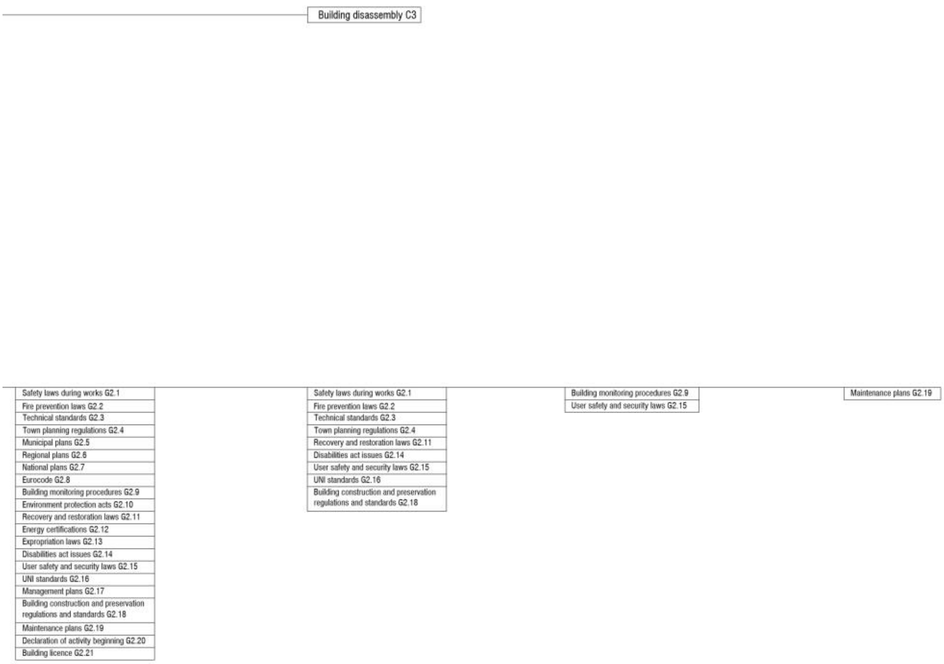
Technical standards G2.3
Municipal plans G2.5
Regional plans G2.6
Disabilities act issues G2.14
User safety and security laws G2.15
UNI standards G2.16
Community support and ownership G3
Building resilience G4


Building disassembly C3
Safety laws during works G2.1
Fire prevention laws G2.2
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Town planning regulations G2.4
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Regional plans G2.6
National plans G2.7
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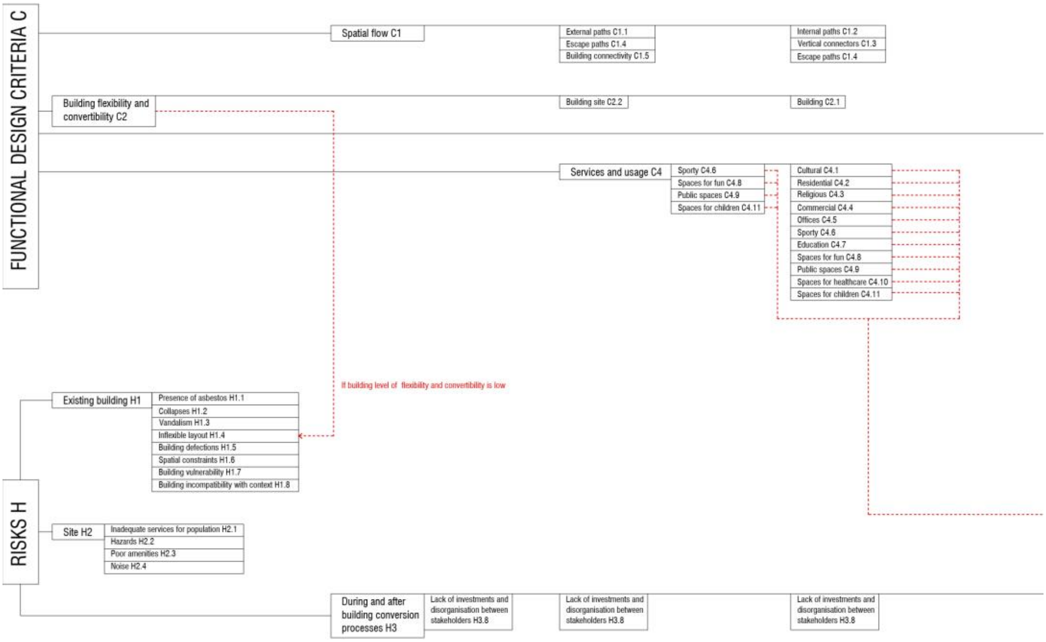
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Internal paths C1.2
Vertical connectors C1.3
Escape paths C1.4
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Building site C2.2
Building C2.1
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Sporty C4.6
Education C4.7
Spaces for fun C4.8
Public spaces C4.9
Spaces for healthcare C4.10
Spaces for children C4.11
If building level of flexibility and convertibility is low
RISKS H
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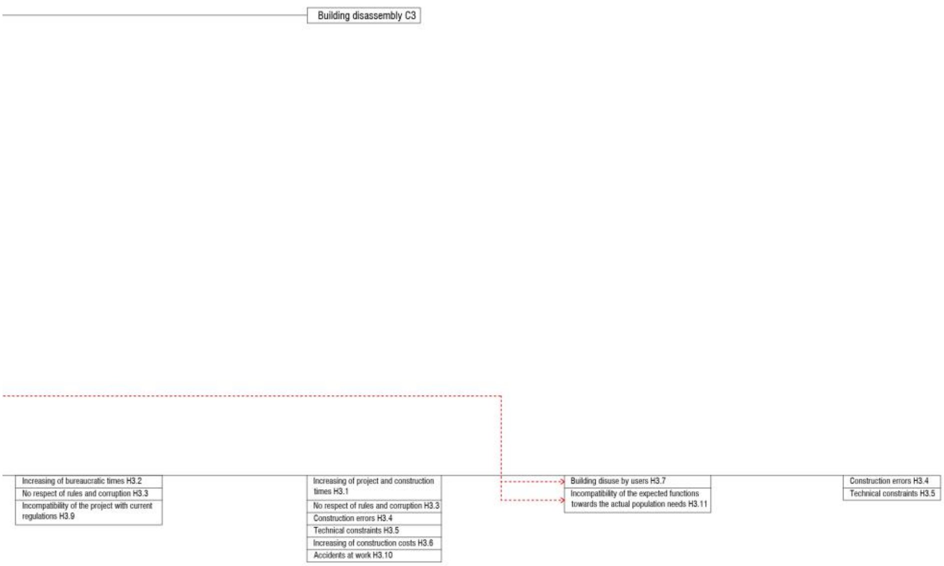
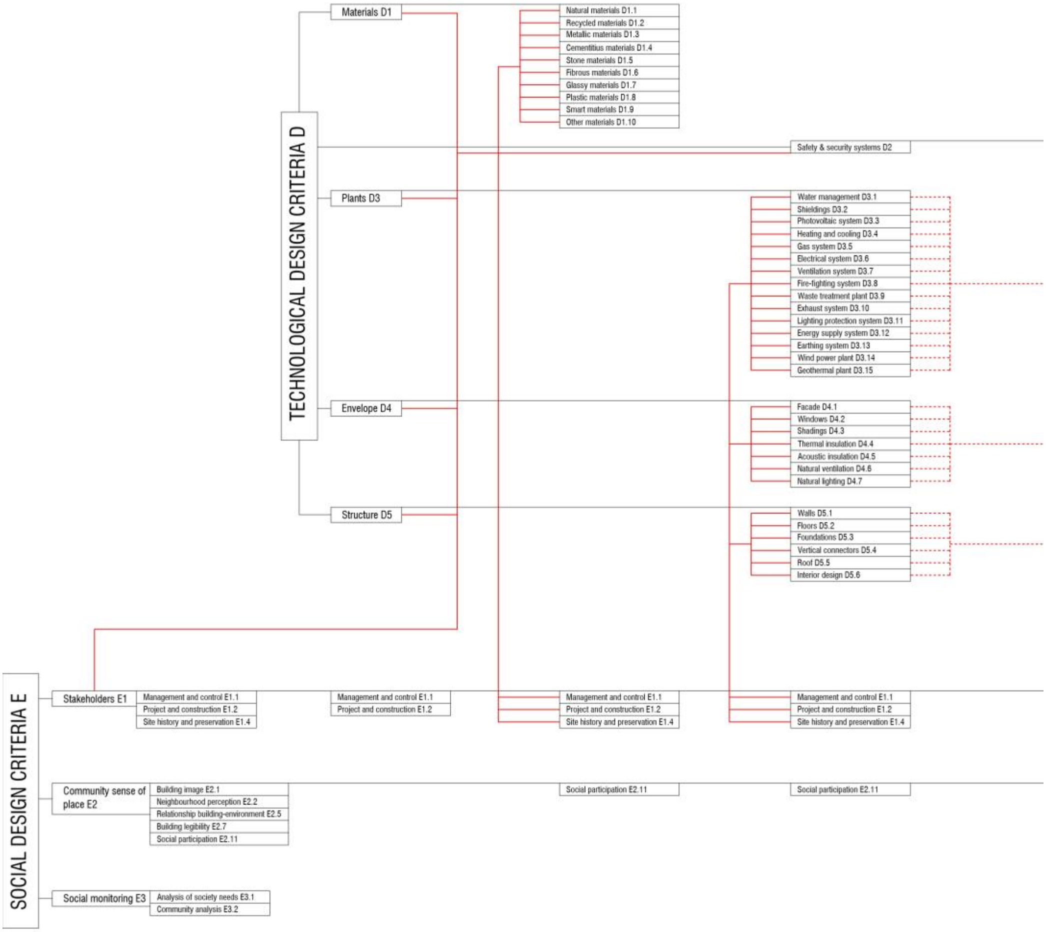
Presence of asbestos H1.1
Collapses H1.2
Vandalism H1.3
Inflexible layout H1.4
Building defections H1.5
Spatial constraints H1.6
Building vulnerability H1.7
Building incompatibility with context H1.8
Site H2
Inadequate services for population H2.1
Hazards H2.2
Poor amenities H2.3
Noise H2.4
During and after building conversion processes H3
Lack of investments and disorganisation between stakeholders H3.8
Lack of investments and disorganisation between stakeholders H3.8
Lack of investments and disorganisation between stakeholders H3.8


Building disassembly C3
Increasing of bureaucratic times H3.2
No respect of rules and corruption H3.3
Incompatibility of the project with current regulations H3.9
Increasing of project and construction times H3.1
No respect of rules and corruption H3.3
Construction errors H3.4
Technical constraints H3.5
Increasing of construction costs H3.6
Accidents at work H3.10
Building disuse by users H3.7
Incompatibility of the expected functions towards the actual population needs H3.11
Construction errors H3.4
Technical constraints H3.5


TECHNOLOGICAL DESIGN CRITERIA D
Materials D1
Natural materials D1.1
Recycled materials D1.2
Metallic materials D1.3
Cementitius materials D1.4
Stone materials D1.5
Fibrous materials D1.6
Glassy materials D1.7
Plastic materials D1.8
Smart materials D1.9
Other materials D1.10
Safety & security systems D2
Plants D3
Water management D3.1
Shieldings D3.2
Photovoltaic system D3.3
Heating and cooling D3.4
Gas system D3.5
Electrical system D3.6
Ventilation system D3.7
Fire-fighting system D3.8
Waste treatment plant D3.9
Exhaust system D3.10
Lighting protection system D3.11
Energy supply system D3.12
Earthing system D3.13
Wind power plant D3.14
Geothermal plant D3.15
Envelope D4
Facade D4.1
Windows D4.2
Shadings D4.3
Thermal insulation D4.4
Acoustic insulation D4.5
Natural ventilation D4.6
Natural lighting D4.7
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Floors D5.2
Foundations D5.3
Vertical connectors D5.4
Roof D5.5
Interior design D5.6
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Project and construction E1.2
Site history and preservation E1.4
Management and control E1.1
Project and construction E1.2
Management and control E1.1
Project and construction E1.2
Site history and preservation E1.4
Management and control E1.1
Project and construction E1.2
Site history and preservation E1.4
Community sense of place E2
Building image E2.1
Neighbourhood perception E2.2
Relationship building-environment E2.5
Building legibility E2.7
Social participation E2.11
Social participation E2.11
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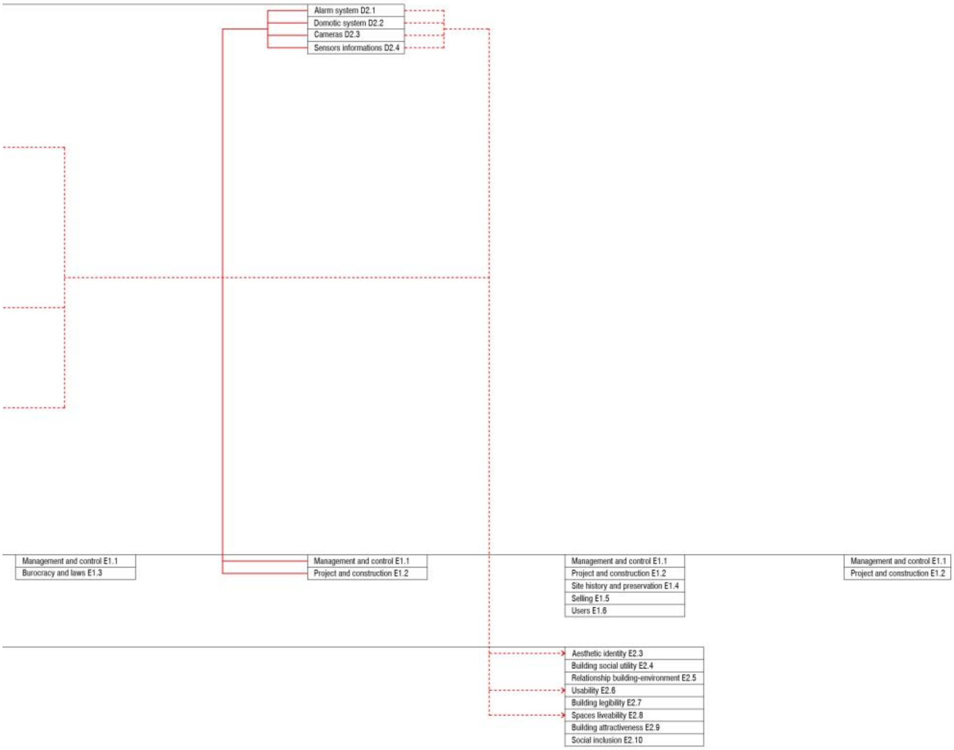
Social monitoring E3
Analysis of society needs E3.1
Community analysis E3.2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Domotic system D2.2
Cameras D2.3
Sensors informations D2.4
Management and control E1.1
Burocracy and laws E1.3
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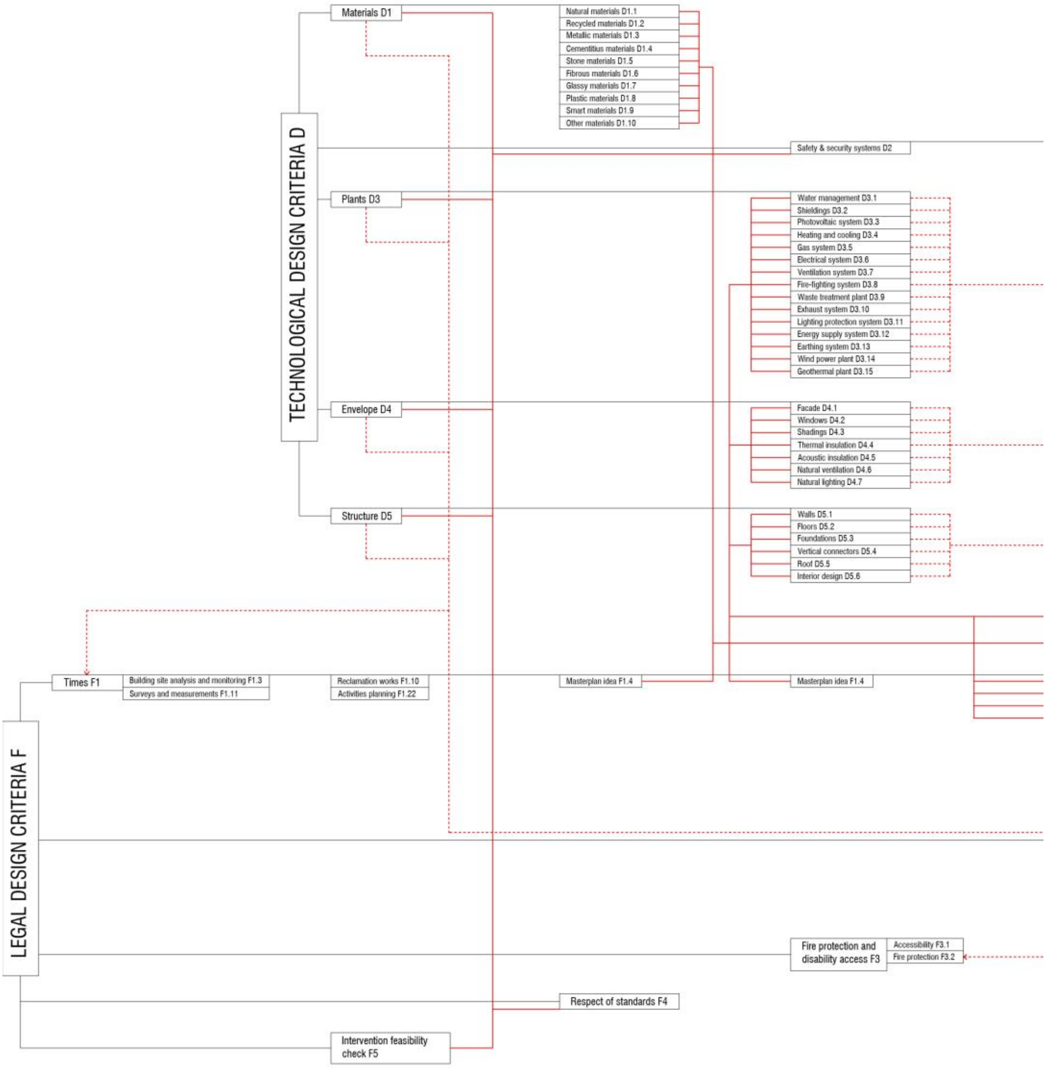
Social inclusion E2.10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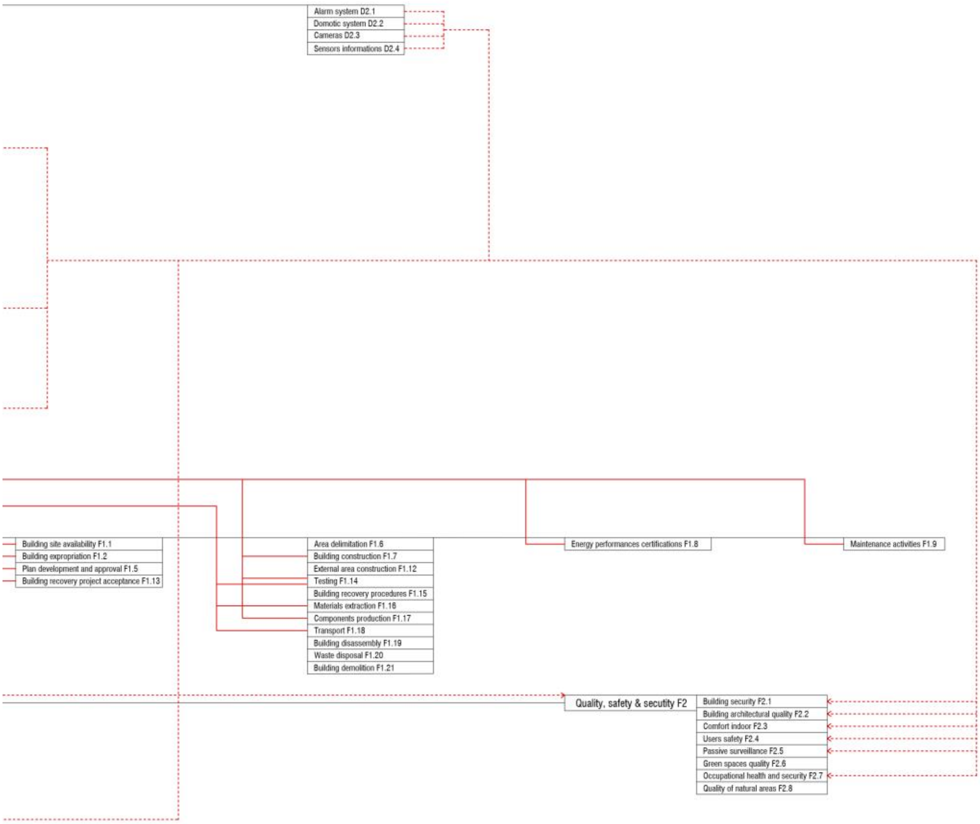

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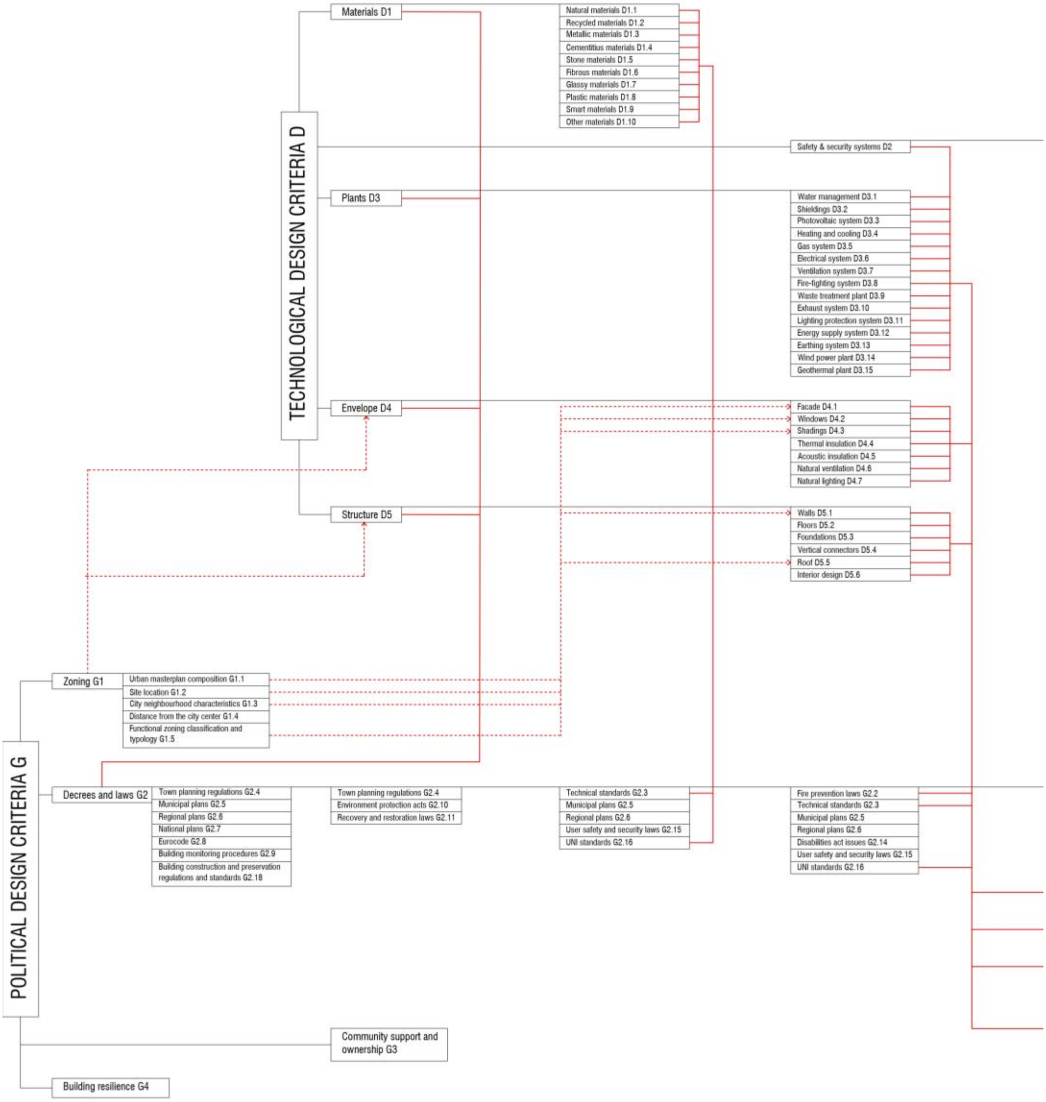
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Community support and ownership G3
Building resilience G4


Alarm system D2.1
Domotic system D2.2
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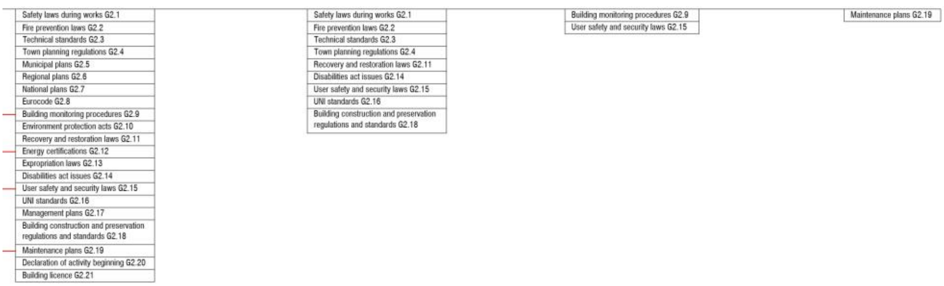
Sensors informations D2.4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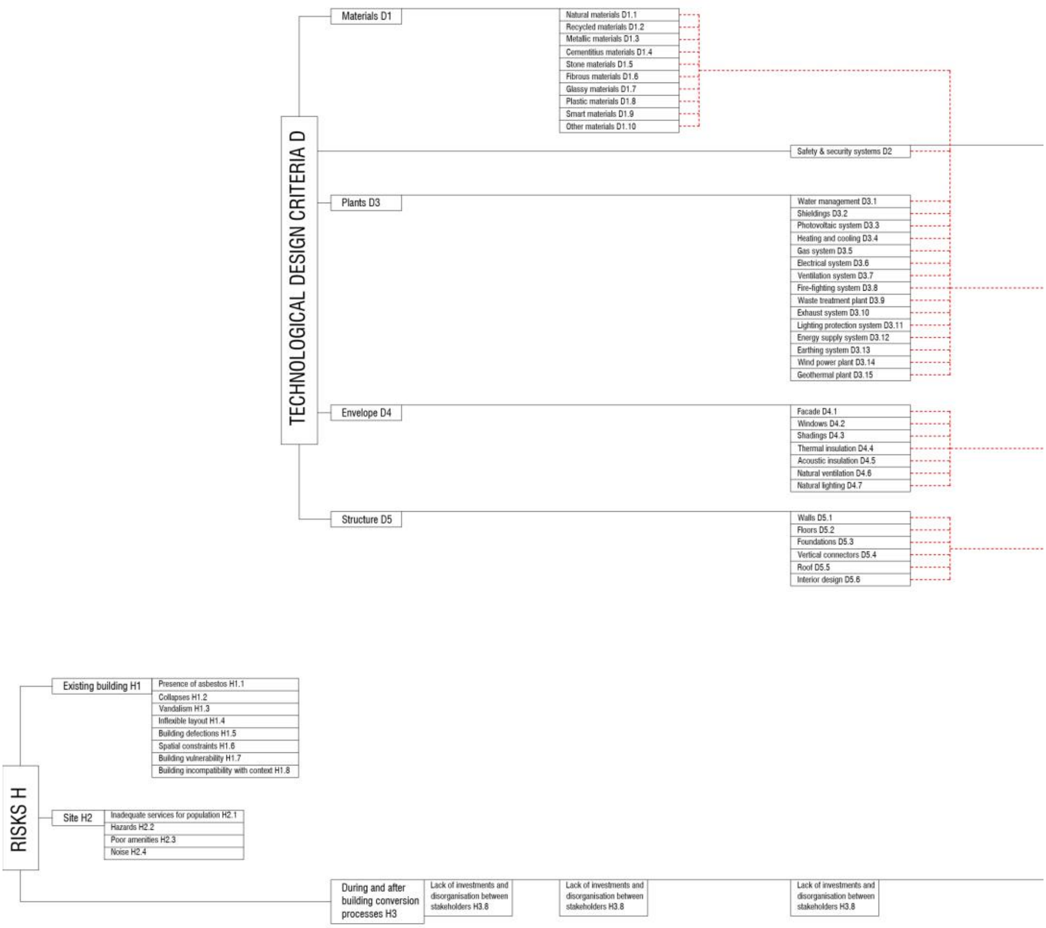
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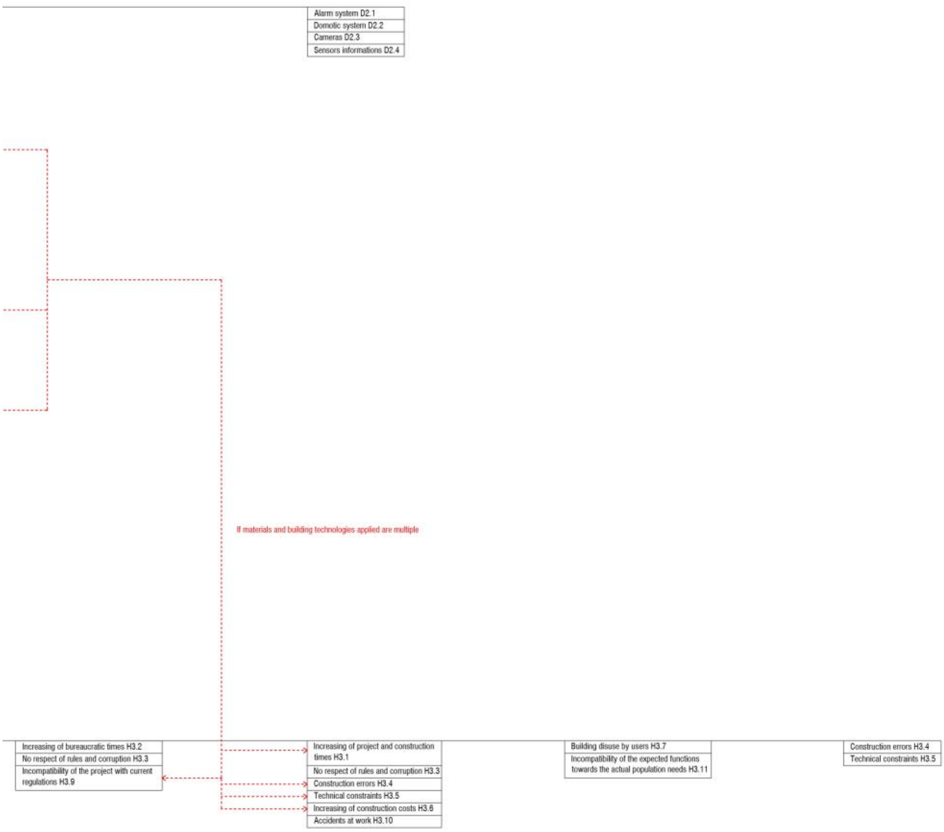
Alarm system D2.1
Domotic system D2.2
Cameras D2.3
Sensors informations D2.4
If materials and building technologies applied are multiple
Increasing of bureaucratic times H3.2
No respect of rules and corruption H3.3
Incompatibility of the project with current regulations H3.9
Increasing of project and construction times H3.1
No respect of rules and corruption H3.3
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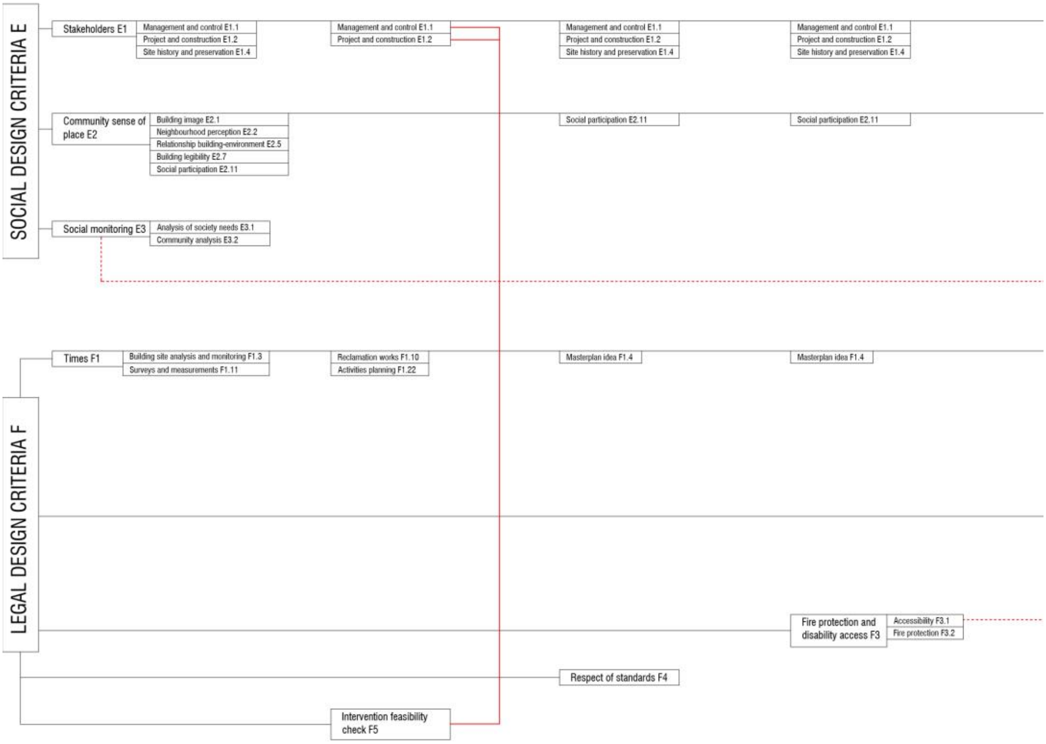
SOCIAL DESIGN CRITERIA E
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Social monitoring E3
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Community analysis E3.2
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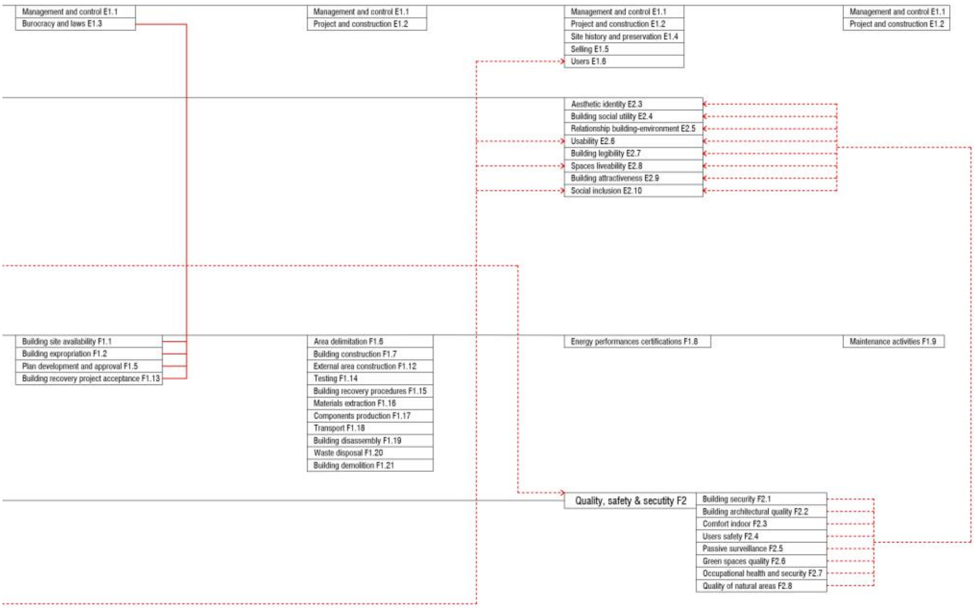
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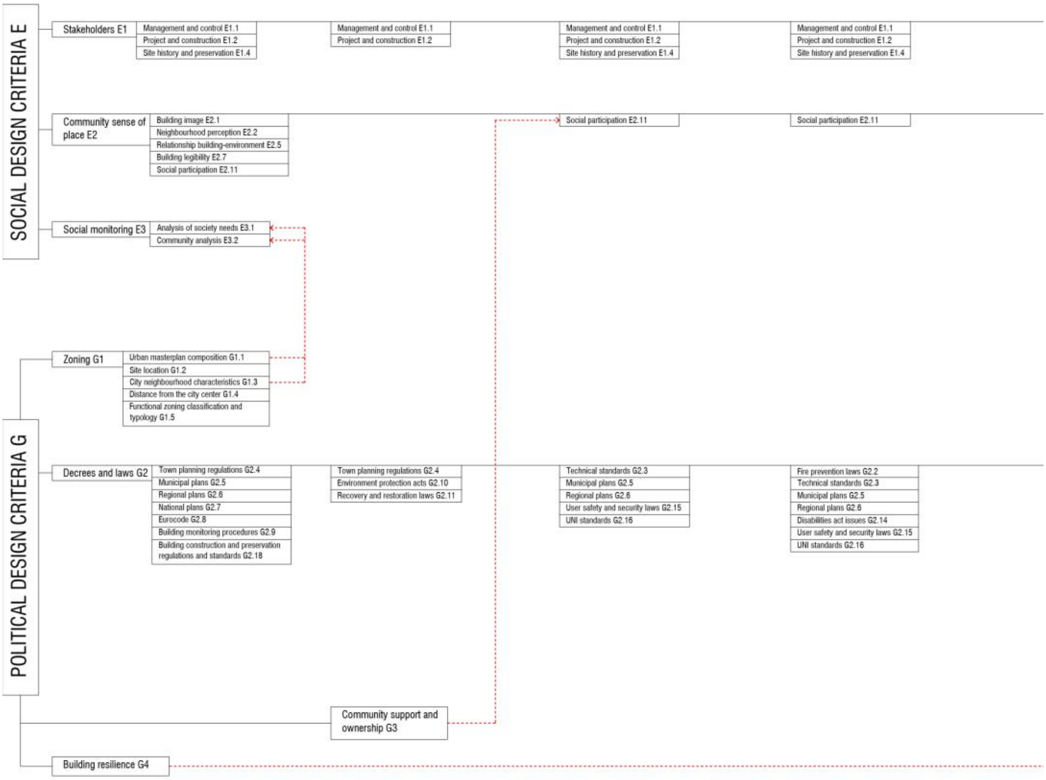
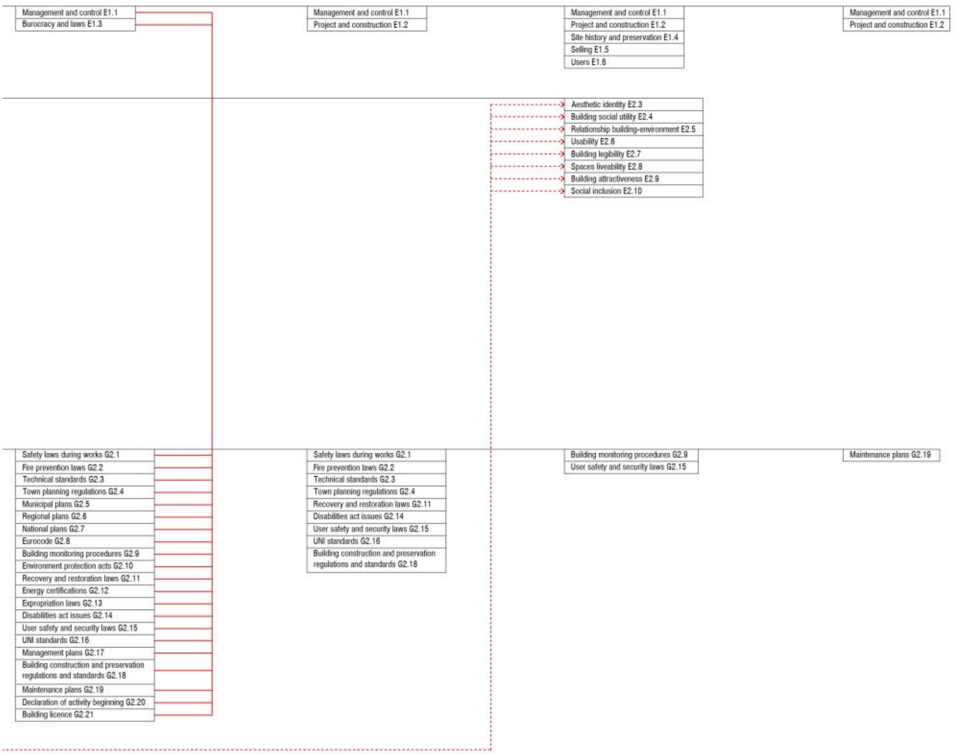
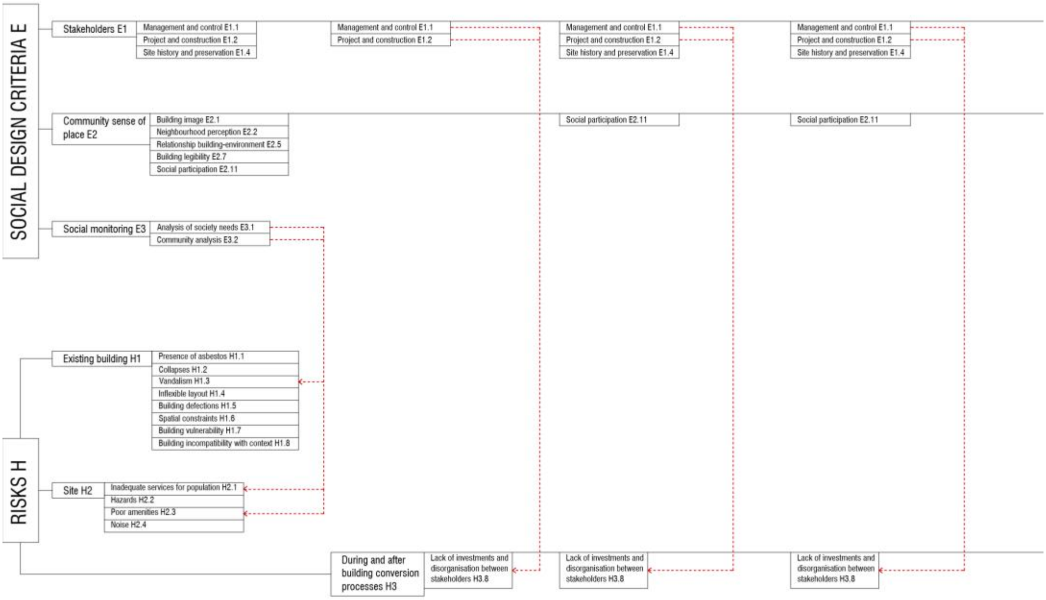
Occupational health and security F2.7
Quality of natural areas F2.8


SOCIAL DESIGN CRITERIA E
Stakeholders E1
Management and control E1.1
Project and construction E1.2
Site history and preservation E1.4
Management and control E1.1
Project and construction E1.2
Management and control E1.1
Project and construction E1.2
Site history and preservation E1.4
Management and control E1.1
Project and construction E1.2
Site history and preservation E1.4
Community sense of place E2
Building image E2.1
Neighbourhood perception E2.2
Relationship building-environment E2.5
Building legibility E2.7
Social participation E2.11
Social participation E2.11
Social participation E2.11
Social monitoring E3
Analysis of society needs E3.1
Community analysis E3.2
POLITICAL DESIGN CRITERIA G
Zoning G1
Urban masterplan composition G1.1
Site location G1.2
City neighbourhood characteristics G1.3
Distance from the city center G1.4
Functional zoning classification and typology G1.5
Decrees and laws G2
Town planning regulations G2.4
Municipal plans G2.5
Regional plans G2.6
National plans G2.7
Eurocode G2.8
Building monitoring procedures G2.9
Building construction and preservation regulations and standards G2.18
Town planning regulations G2.4
Environment protection acts G2.10
Recovery and restoration laws G2.11
Technical standards G2.3
Municipal plans G2.5
Regional plans G2.6
User safety and security laws G2.15
UNI standards G2.16
Fire prevention laws G2.2
Technical standards G2.3
Municipal plans G2.5
Regional plans G2.6
Disabilities act issues G2.14
User safety and security laws G2.15
UNI standards G2.16
Community support and ownership G3
Building resilience G4



Management and control E1.1
Burocracy and laws E1.3
Management and control E1.1
Project and construction E1.2
Management and control E1.1
Project and construction E1.2
Site history and preservation E1.4
Selling E1.5
Users E1.6
Management and control E1.1
Project and construction E1.2
Aesthetic identity E2.3
Building social utility E2.4
Relationship building-environment E2.5
Usability E2.6
Building legibility E2.7
Spaces liveability E2.8
Building attractiveness E2.9
Social inclusion E2.10
Safety laws during works G2.1
Fire prevention laws G2.2
Technical standards G2.3
Town planning regulations G2.4
Municipal plans G2.5
Regional plans G2.6
National plans G2.7
Eurocode G2.8
Building monitoring procedures G2.9
Environment protection acts G2.10
Recovery and restoration laws G2.11
Energy certifications G2.12
Expropriation laws G2.13
Disabilities act issues G2.14
User safety and security laws G2.15
UNI standards G2.16
Management plans G2.17
Building construction and preservation regulations and standards G2.18
Maintenance plans G2.19
Declaration of activity beginning G2.20
Building licence G2.21
Safety laws during works G2.1
Fire prevention laws G2.2
Technical standards G2.3
Town planning regulations G2.4
Recovery and restoration laws G2.11
Disabilities act issues G2.14
User safety and security laws G2.15
UNI standards G2.16
Building construction and preservation regulations and standards G2.18
Building monitoring procedures G2.9
User safety and security laws G2.15
Maintenance plans G2.19



SOCIAL DESIGN CRITERIA E
Stakeholders E1
Management and control E1.1
Project and construction E1.2
Site history and preservation E1.4
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Building image E2.1
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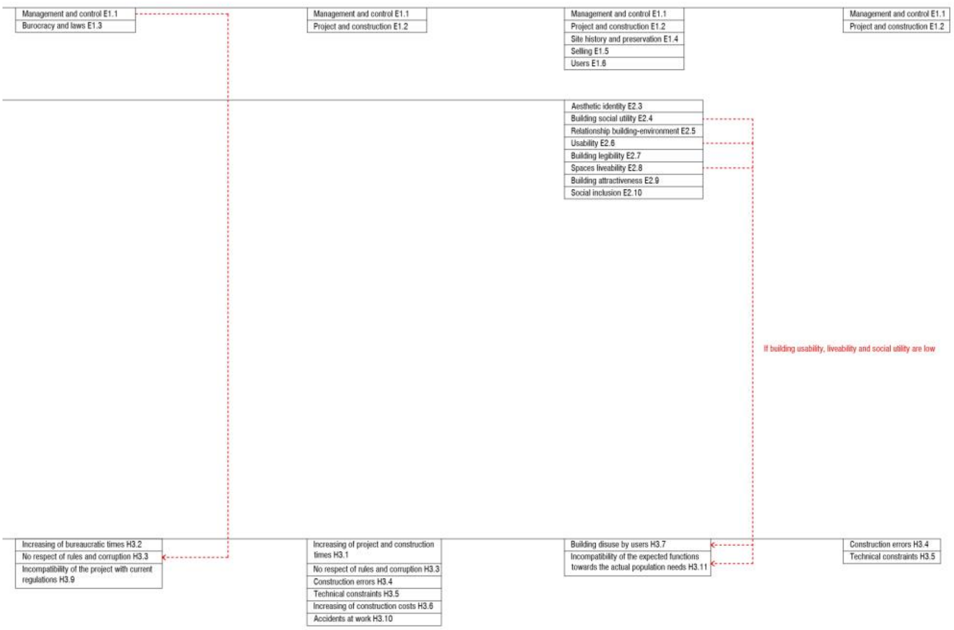
Building legibility E2.7
Social participation E2.11
Social monitoring E3
Analysis of society needs E3.1
Community analysis E3.2
RISKS H
Existing building H1
Presence of asbestos H1.1
Collapses H1.2
Vandalism H1.3
Inflexible layout H1.4
Building defections H1.5
Spatial constraints H1.6
Building vulnerability H1.7
Building incompatibility with context H1.8
Site H2
Inadequate services for population H2.1
Hazards H2.2
Poor amenities H2.3
Noise H2.4
During and after building conversion processes H3
Lack of investments and disorganisation between stakeholders H3.8



Management and control E1.1
Burocracy and laws E1.3
Management and control E1.1
Project and construction E1.2
Management and control E1.1
Project and construction E1.2
Site history and preservation E1.4
Selling E1.5
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Project and construction E1.2
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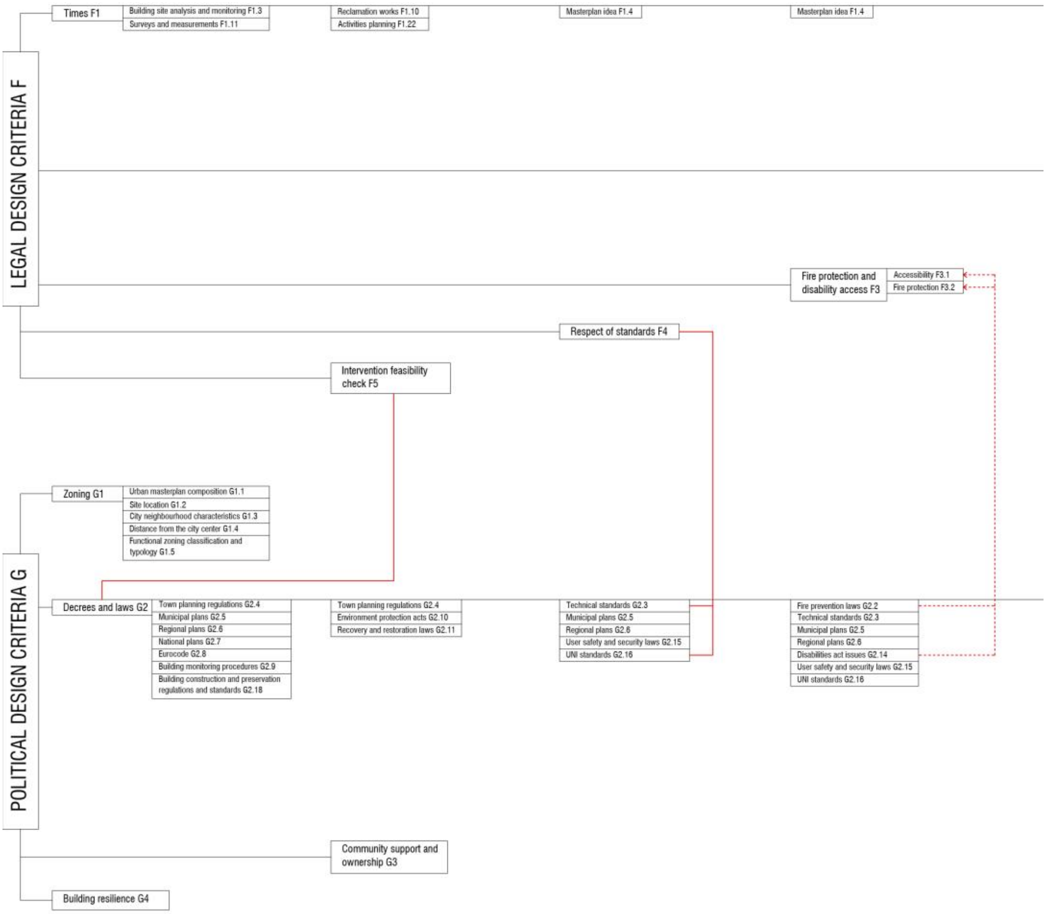
Relationship building-environment E2.5
Usability E2.6
Building legibility E2.7
Spaces liveability E2.8
Building attractiveness E2.9
Social inclusion E2.10
If building usability, liveability and social utility are low
Increasing of bureaucratic times H3.2
No respect of rules and corruption H3.3
Incompatibility of the project with current regulations H3.9
Increasing of project and construction times H3.1
No respect of rules and corruption H3.3
Construction errors H3.4
Technical constraints H3.5
Increasing of construction costs H3.6
Accidents at work H3.10
Building disuse by users H3.7
Incompatibility of the expected functions towards the actual population needs H3.11
Construction errors H3.4
Technical constraints H3.5


LEGAL DESIGN CRITERIA F
Times F1
Building site analysis and monitoring F1.3
Surveys and measurements F1.11
Reclamation works F1.10
Activities planning F1.22
Masterplan idea F1.4
Masterplan idea F1.4
Fire protection and disability access F3
Accessibility F3.1
Fire protection F3.2
Respect of standards F4
Intervention feasibility check F5
POLITICAL DESIGN CRITERIA G
Zoning G1
Urban masterplan composition G1.1
Site location G1.2
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Municipal plans G2.5
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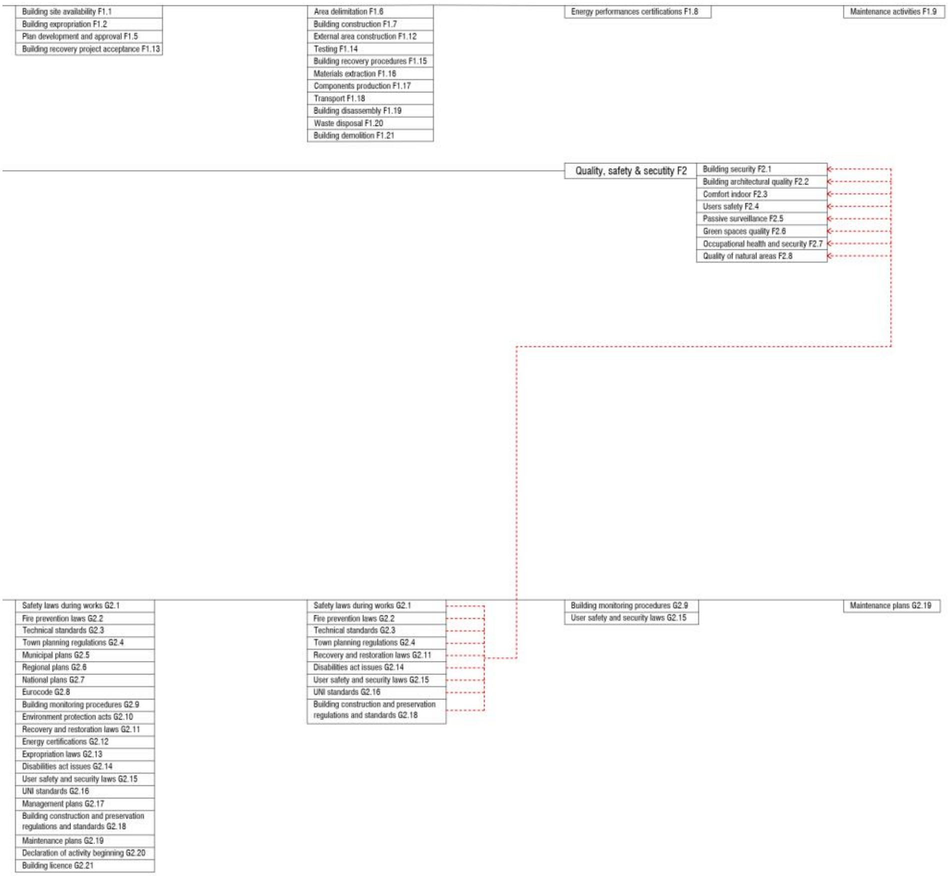
Disabilities act issues G2.14
User safety and security laws G2.15
UNI standards G2.16
Community support and ownership G3
Building resilience G4


Building site availability F1.1
Building expropriation F1.2
Plan development and approval F1.5
Building recovery project acceptance F1.13
Area delimitation F1.6
Building construction F1.7
External area construction F1.12
Testing F1.14
Building recovery procedures F1.15
Materials extraction F1.16
Components production F1.17
Transport F1.18
Building disassembly F1.19
Waste disposal F1.20
Building demolition F1.21
Energy performances certifications F1.8
Maintenance activities F1.9
Quality, safety & secutity F2
Building security F2.1
Building architectural quality F2.2
Comfort indoor F2.3
Users safety F2.4
Passive surveillance F2.5
Green spaces quality F2.6
Occupational health and security F2.7
Quality of natural areas F2.8
Safety laws during works G2.1
Fire prevention laws G2.2
Technical standards G2.3
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Building monitoring procedures G2.9
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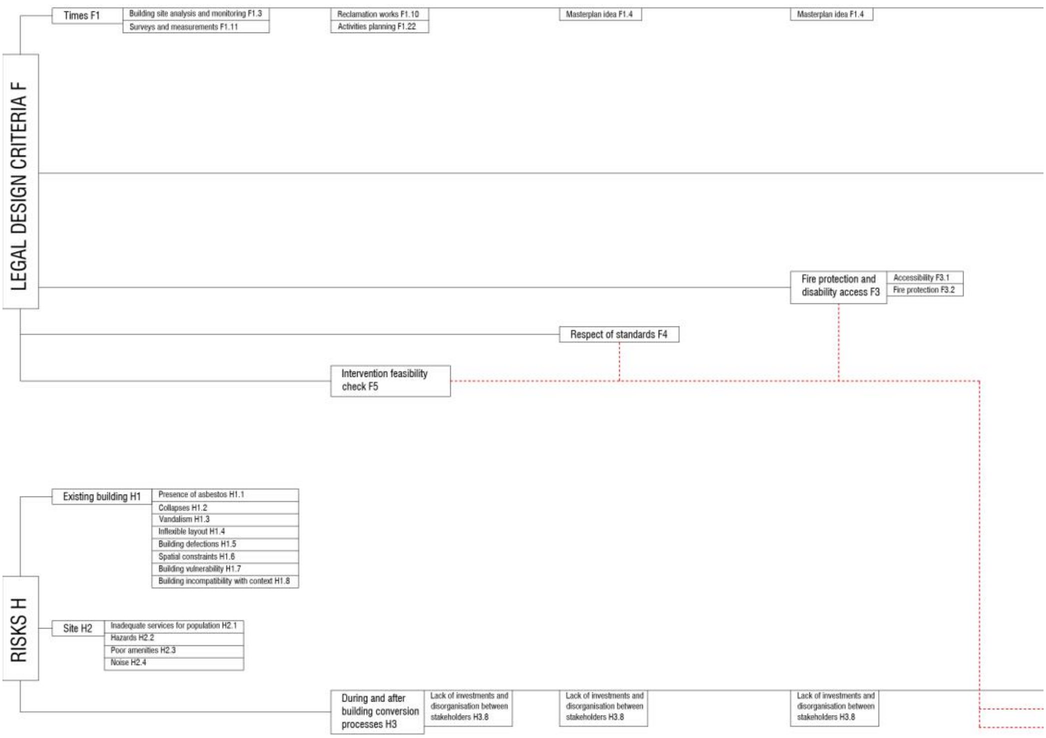
Maintenance plans G2.19


LEGAL DESIGN CRITERIA F
Times F1
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Surveys and measurements F1.11
Reclamation works F1.10
Activities planning F1.22
Masterplan idea F1.4
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Fire protection and disability access F3
Accessibility F3.1
Fire protection F3.2
Respect of standards F4
Intervention feasibility check F5
RISKS H
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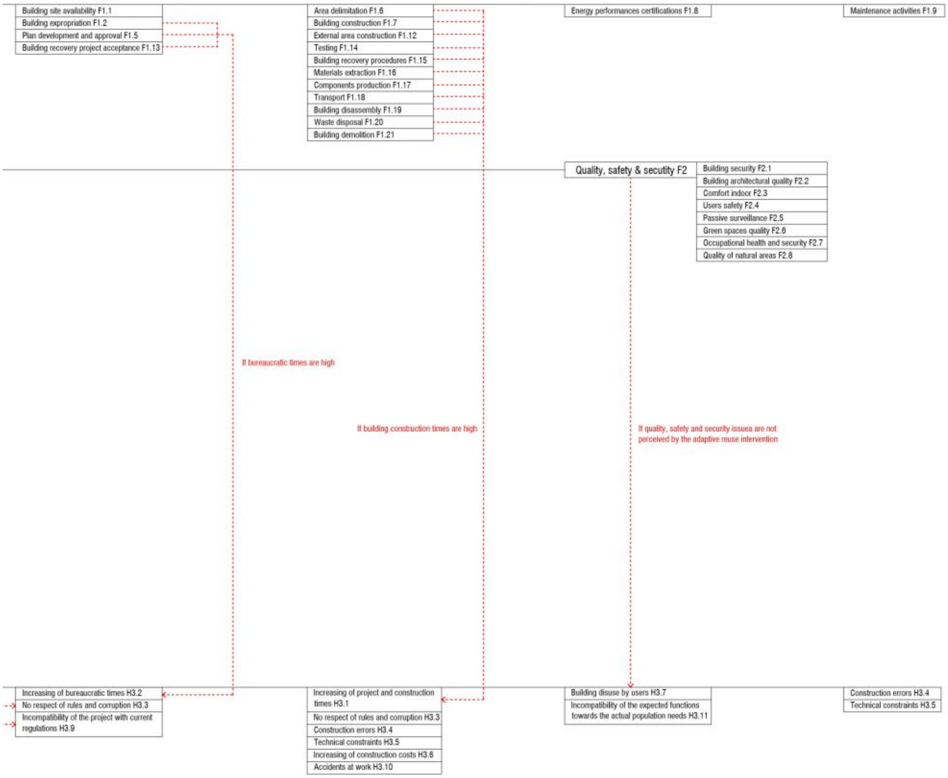
Collapses H1.2
Vandalism H1.3
Inflexible layout H1.4
Building defections H1.5
Spatial constraints H1.6
Building vulnerability H1.7
Building incompatibility with context H1.8
Site H2
Inadequate services for population H2.1
Hazards H2.2
Poor amenities H2.3
Noise H2.4
During and after building conversion processes H3
Lack of investments and disorganisation between stakeholders H3.8
Lack of investments and disorganisation between stakeholders H3.8
Lack of investments and disorganisation between stakeholders H3.8


Building site availability F1.1
Building expropriation F1.2
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Building recovery project acceptance F1.13
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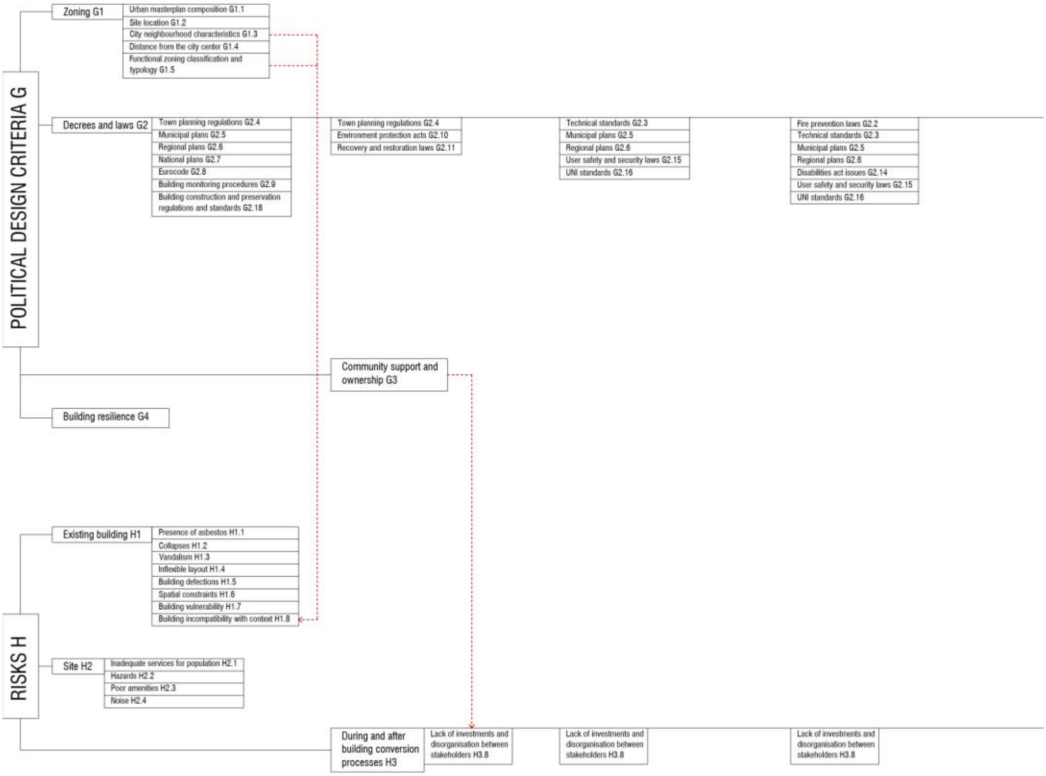
Energy performances certifications F1.8
Maintenance activities F1.9
Quality, safety & secutity F2
Building security F2.1
Building architectural quality F2.2
Comfort indoor F2.3
Users safety F2.4
Passive surveillance F2.5
Green spaces quality F2.6
Occupational health and security F2.7
Quality of natural areas F2.8
If bureaucratic times are high
If building construction times are high
If quality, safety and security issuea are not perceived by the adaptive reuse intervention
Increasing of bureaucratic times H3.2
No respect of rules and corruption H3.3
Incompatibility of the project with current regulations H3.9
Increasing of project and construction times H3.1
No respect of rules and corruption H3.3
Construction errors H3.4
Technical constraints H3.5
Increasing of construction costs H3.6
Accidents at work H3.10
Building disuse by users H3.7
Incompatibility of the expected functions towards the actual population needs H3.11
Construction errors H3.4
Technical constraints H3.5



POLITICAL DESIGN CRITERIA G
Zoning G1
Urban masterplan composition G1.1
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Regional plans G2.6
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UNI standards G2.16
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Building resilience G4
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Vandalism H1.3
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Building vulnerability H1.7
Building incompatibility with context H1.8
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Noise H2.4
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Lack of investments and disorganisation between stakeholders H3.8
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Lack of investments and disorganisation between stakeholders H3.8

Safety laws during works G2.1
Fire prevention laws G2.2
Technical standards G2.3
Town planning regulations G2.4
Municipal plans G2.5
Regional plans G2.6
National plans G2.7
Eurocode G2.8
Building monitoring procedures G2.9
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Recovery and restoration laws G2.11
Energy certifications G2.12
Expropriation laws G2.13
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Fire prevention laws G2.2
Technical standards G2.3
Town planning regulations G2.4
Recovery and restoration laws G2.11
Disabilities act issues G2.14
User safety and security laws G2.15
UNI standards G2.16
Building construction and preservation regulations and standards G2.18

Building monitoring procedures G2.9
User safety and security laws G2.15

Maintenance plans G2.19

Increasing of bureaucratic times H3.2
No respect of rules and corruption H3.3
Incompatibility of the project with current regulations H3.9

Increasing of project and construction times H3.1
No respect of rules and corruption H3.3
Construction errors H3.4
Technical constraints H3.5
Increasing of construction costs H3.6
Accidents at work H3.10

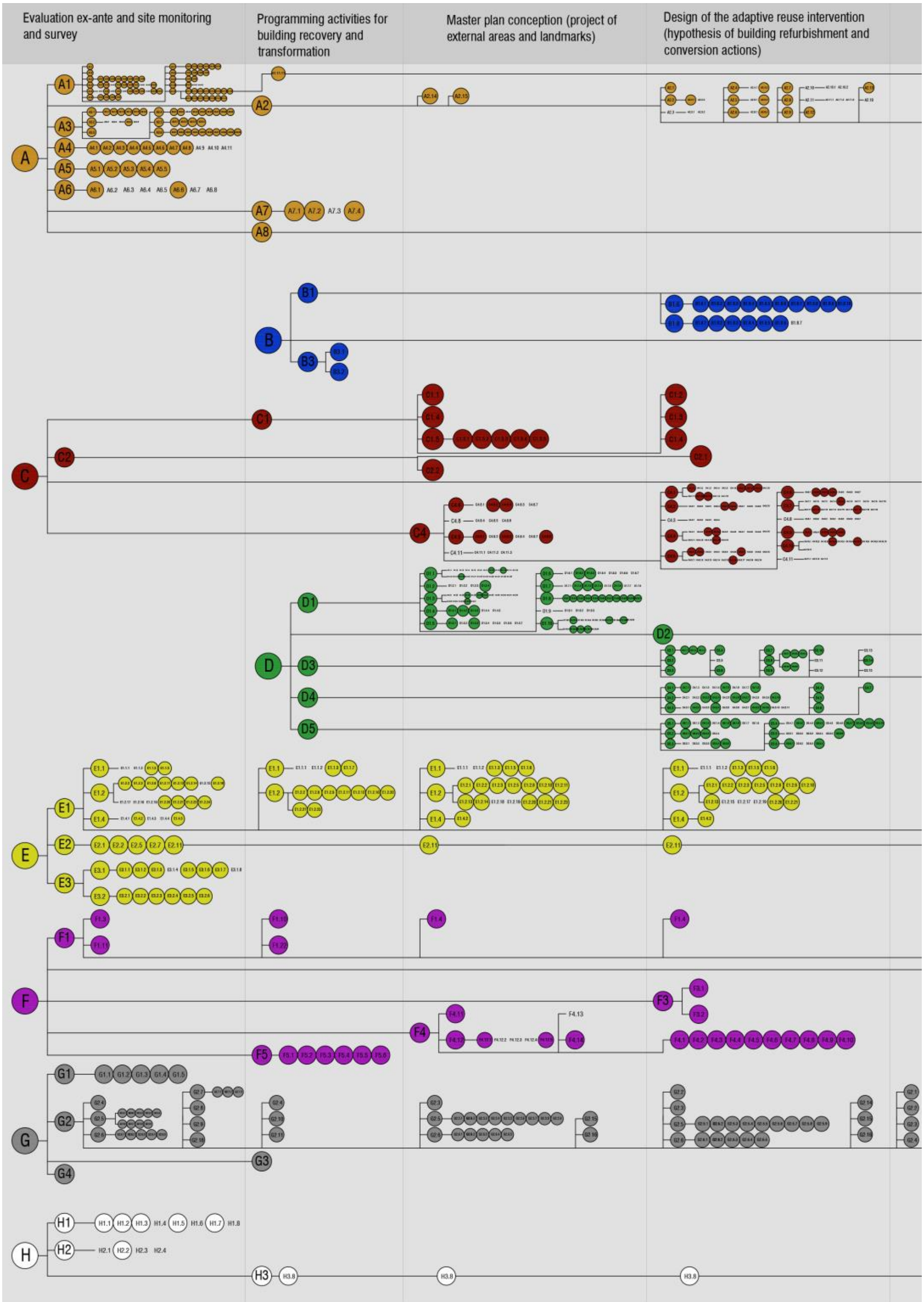
Building disuse by users H3.7
Incompatibility of the expected functions towards the actual population needs H3.11

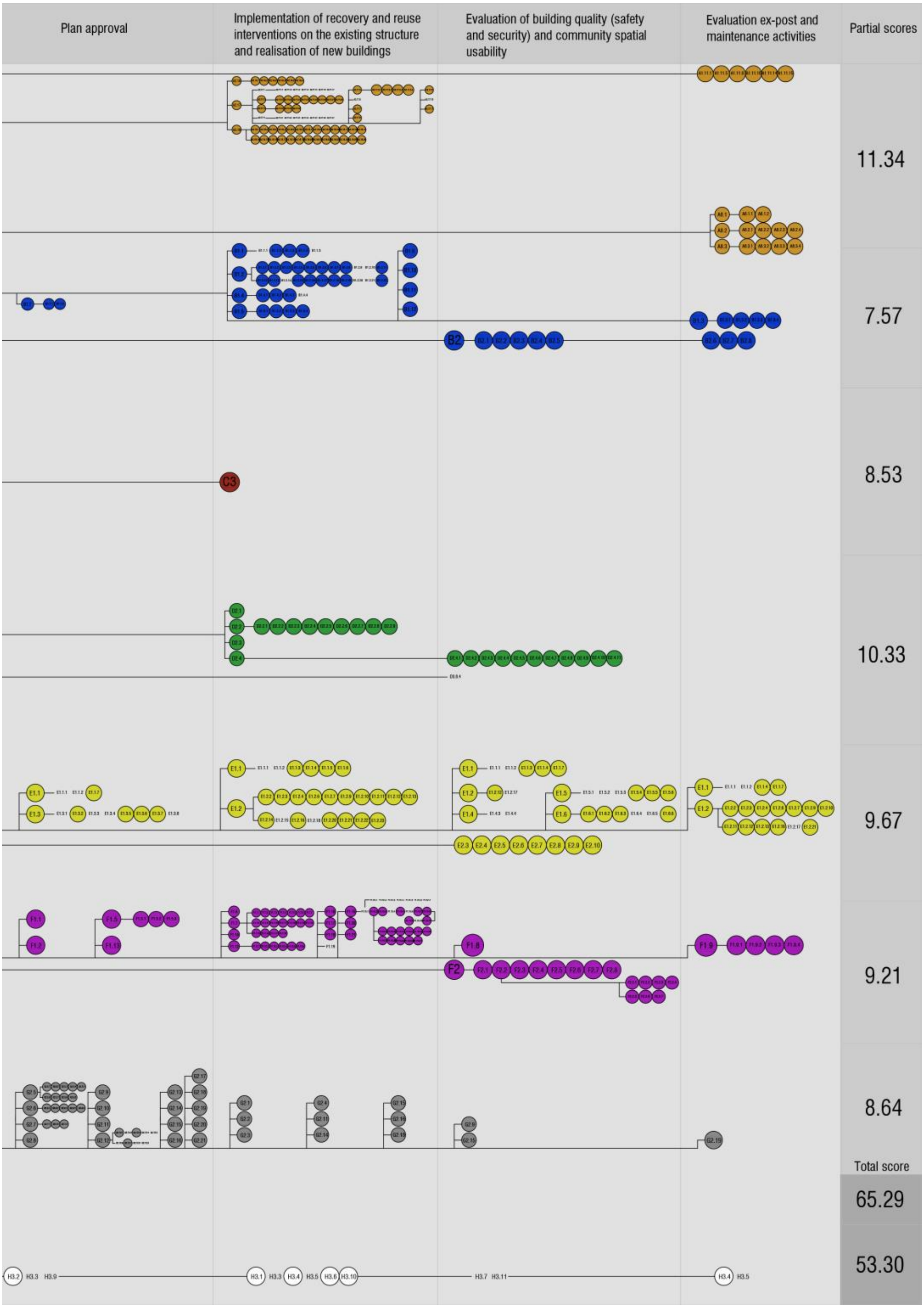
Construction errors H3.4
Technical constraints H3.5

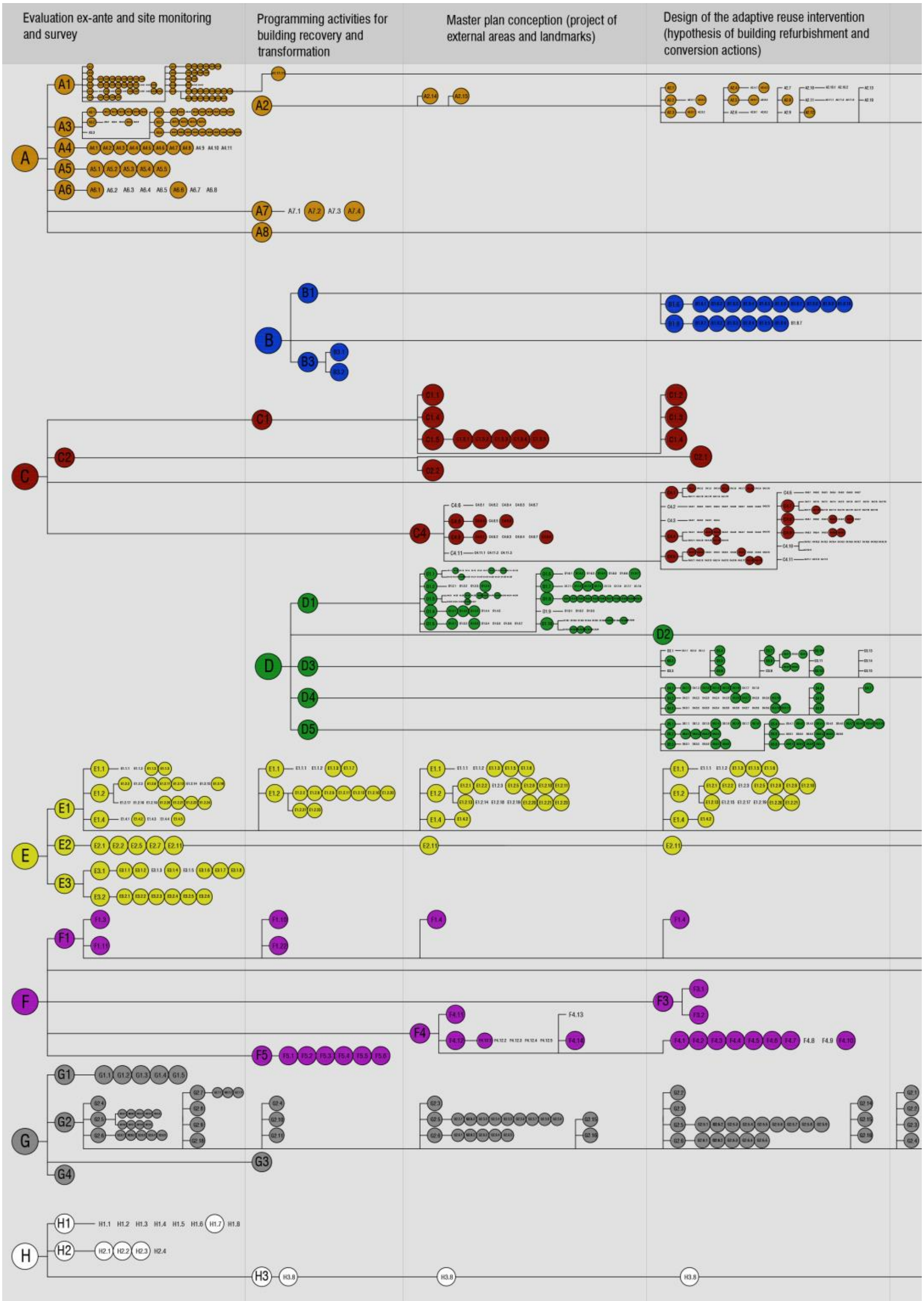
ANNEX D

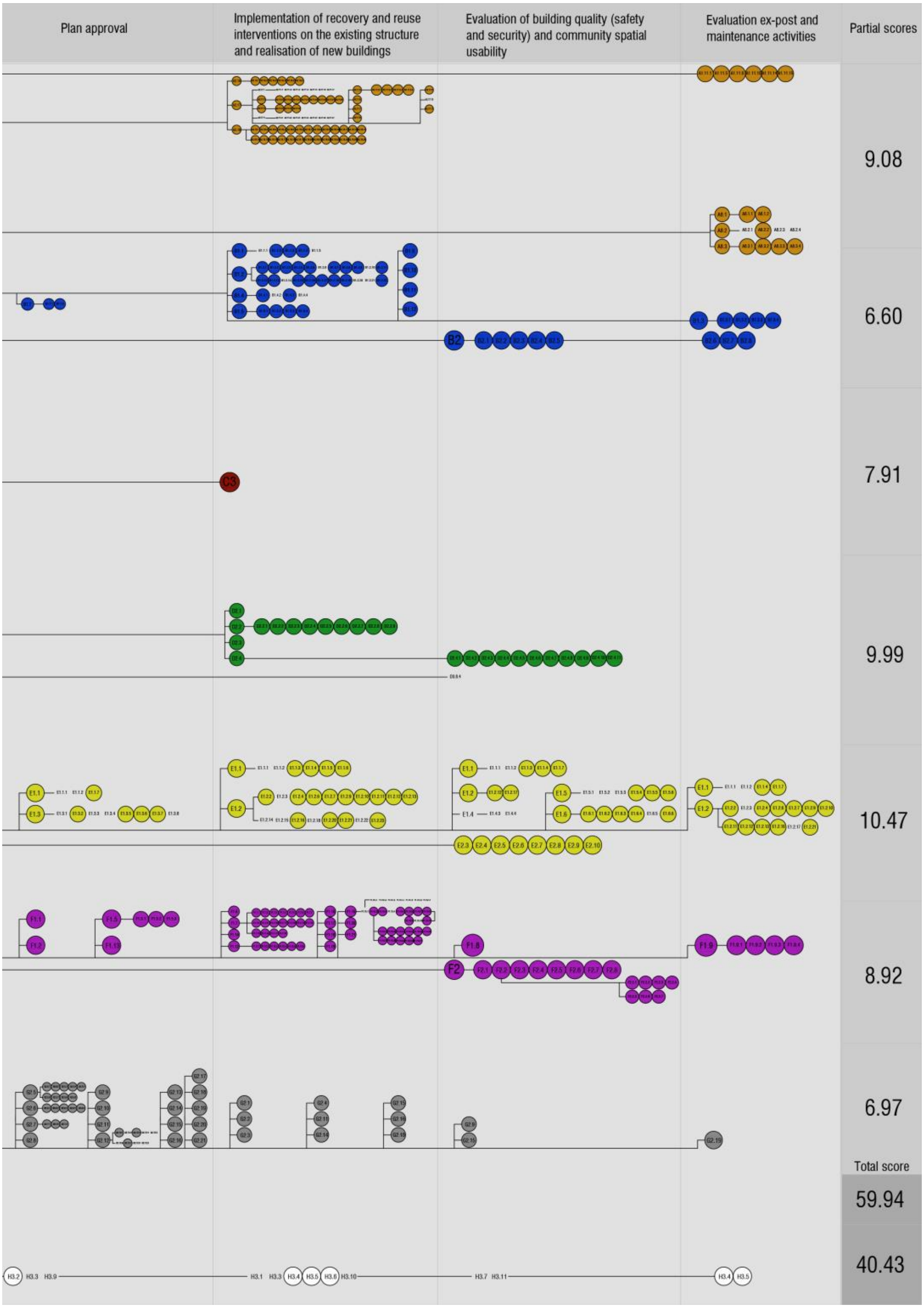
(Final flowcharts of adaptive reuse strategies provided for each case of industrial re-furbishment, using the building recovery table)

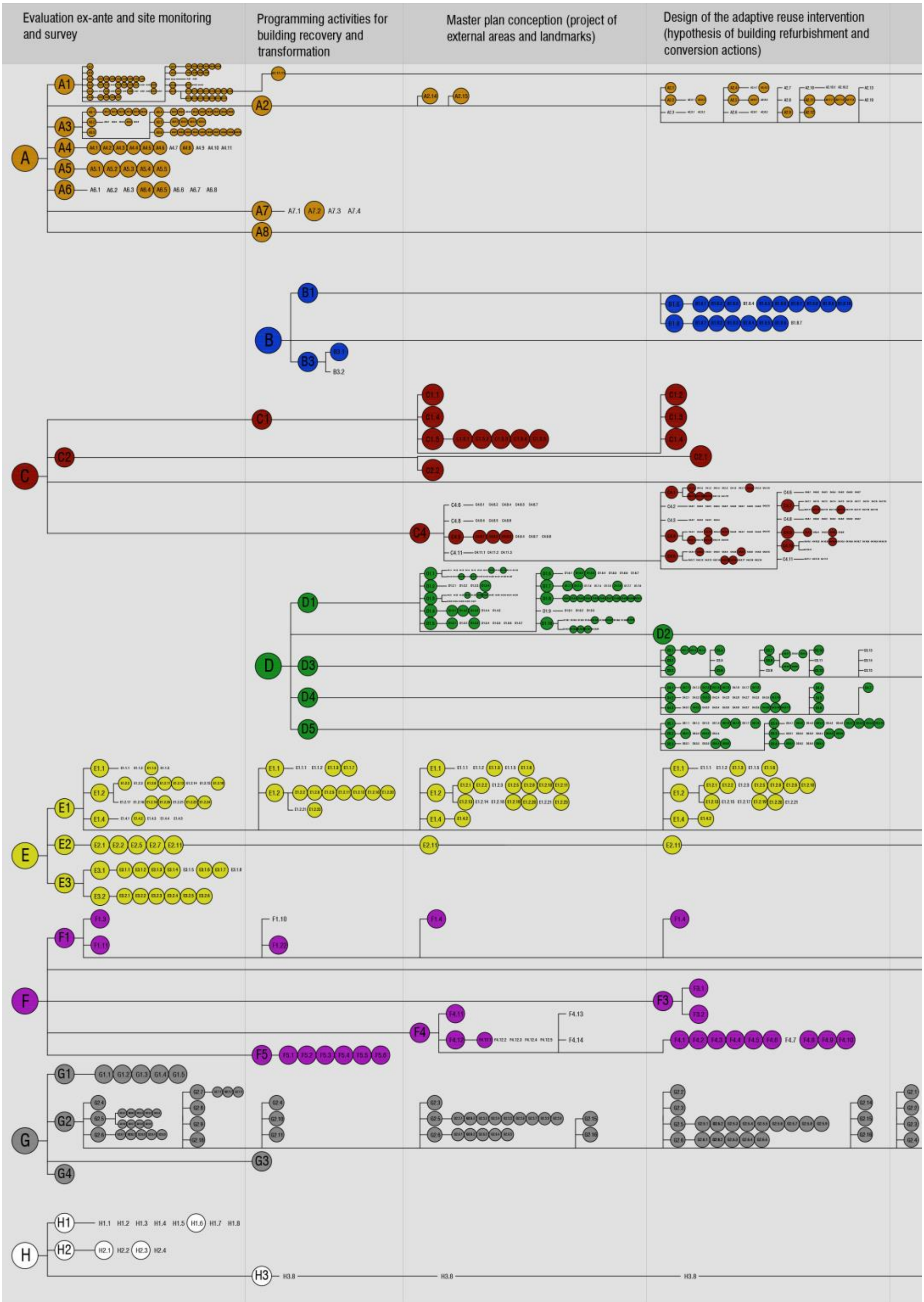
1. *Former Manifattura Tabacchi industrial site;*
2. *Former Radaelli Sud factory;*
3. *Former Divania site;*
4. *Former STANIC refinery;*
5. *Former ENEL power plant;*

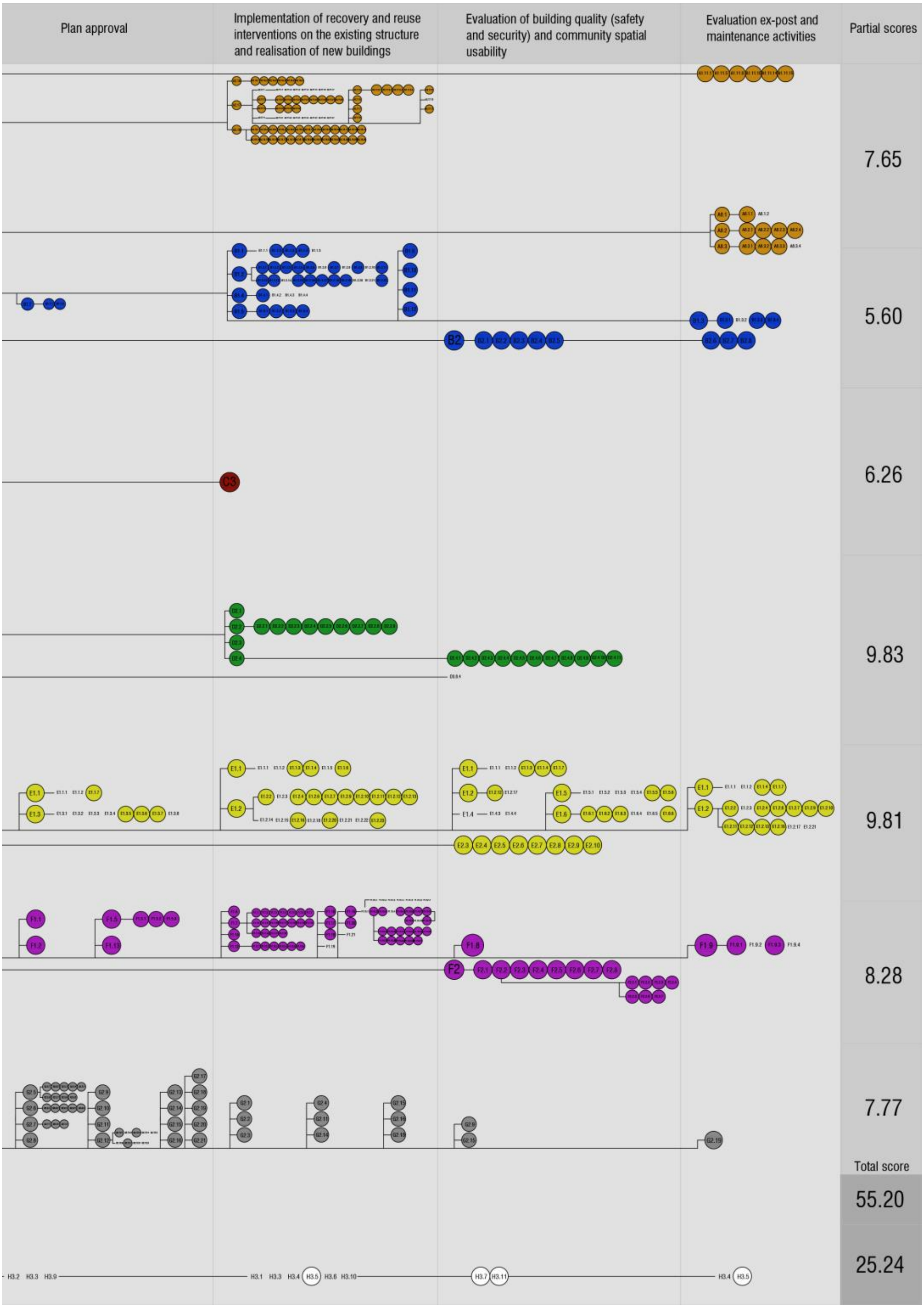

Evaluation ex-ante and site monitoring and survey
Programming activities for building recovery and transformation
Master plan conception (project of external areas and landmarks)
Design of the adaptive reuse intervention (hypothesis of building refurbishment and conversion actions)
A
A1
A2
A3
A4
A5
A6
A7
A8
B
B1
B3
C
C1
C2
C4
D
D1
D2
D3
D4
D5
E
E1
E2
E3
F
F1
F3
F4
F5
G
G1
G2
G3
G4
H
H1
H2
H3

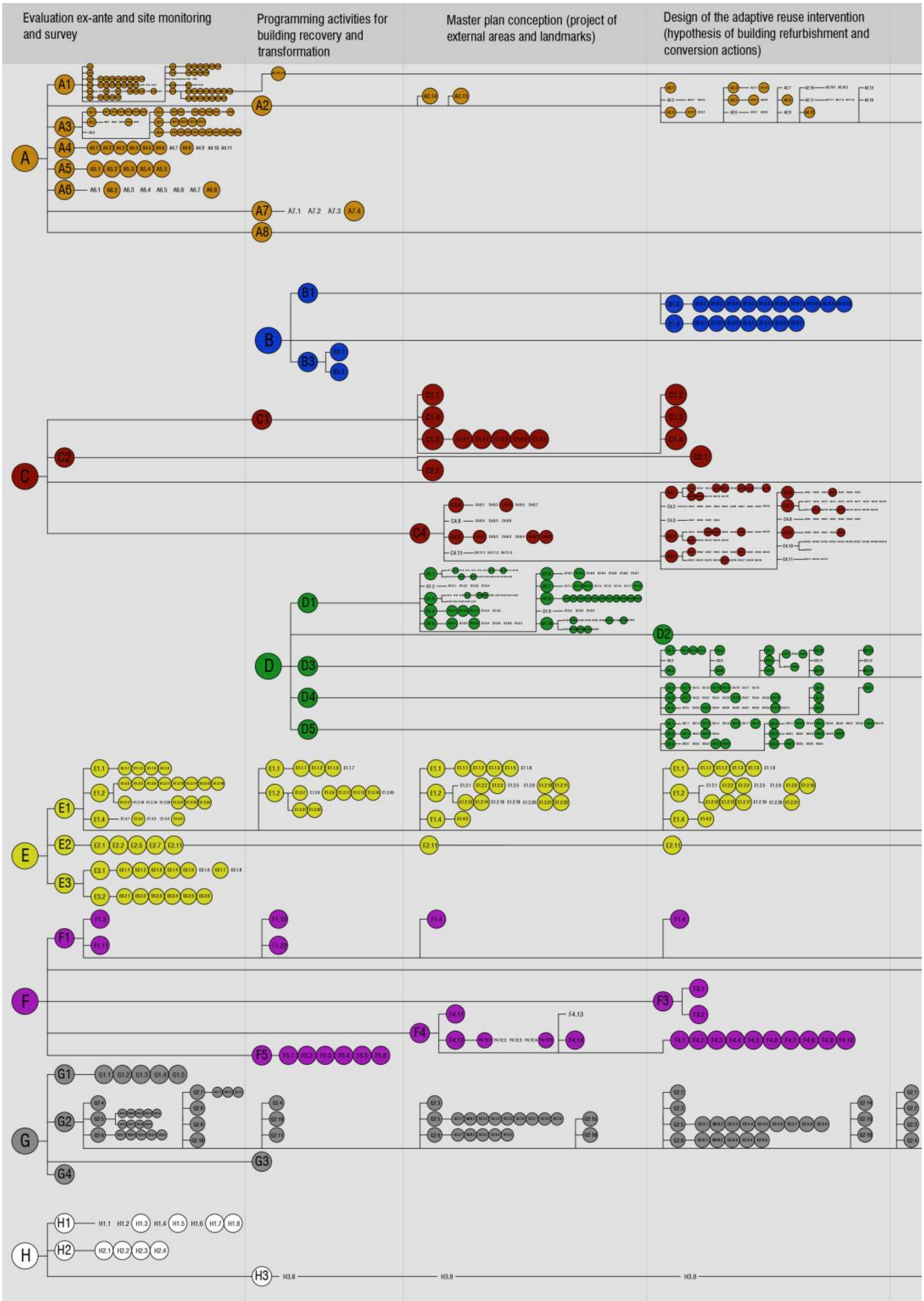

Plan approval
Implementation of recovery and reuse interventions on the existing structure and realisation of new buildings
Evaluation of building quality (safety and security) and community spatial usability
Evaluation ex-post and maintenance activities
Partial scores
11.34
7.57
8.53
10.33
9.67
9.21
8.64
Total score
65.29
53.30
B2
C3
F2
F1.8
F1.9

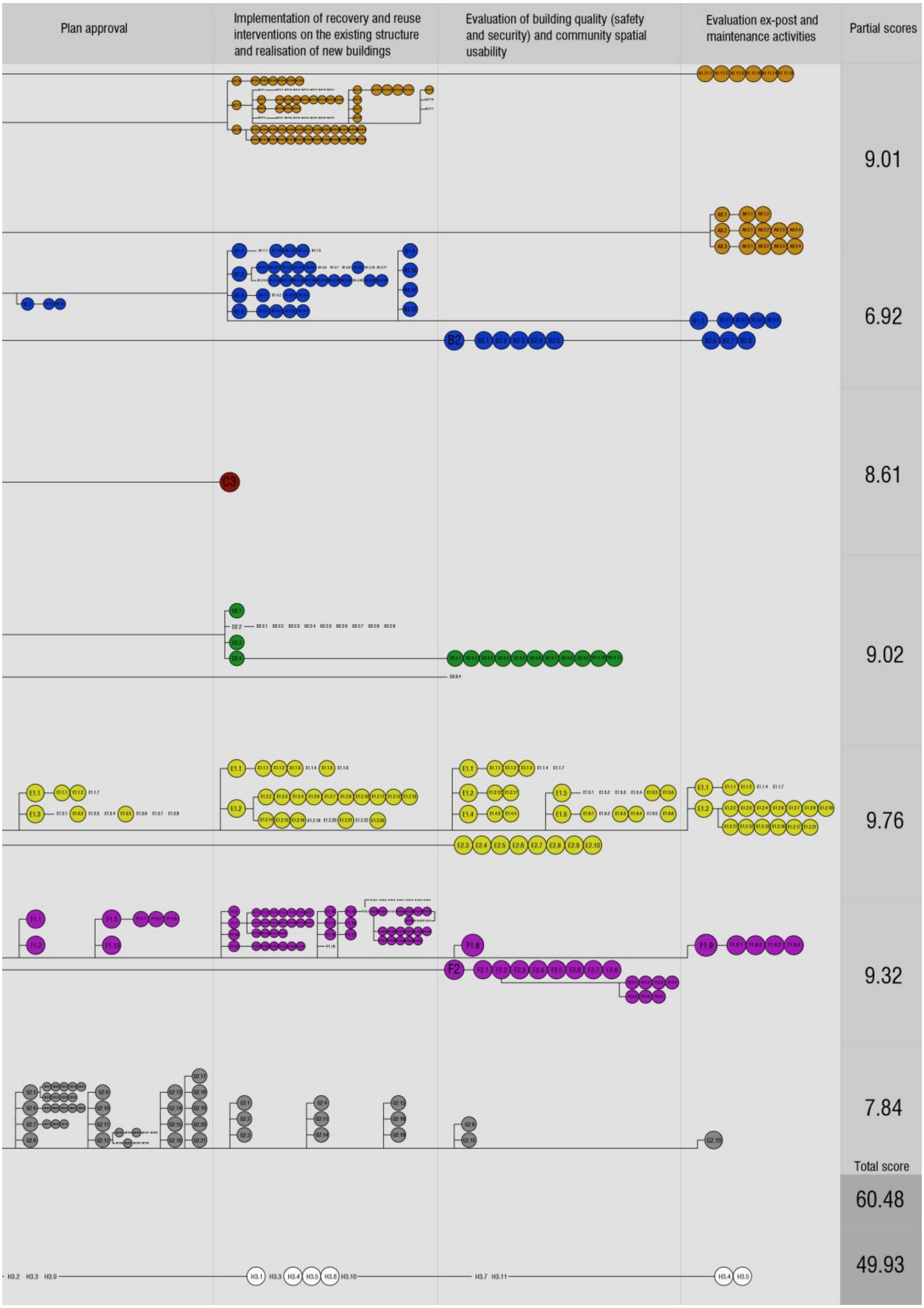

Evaluation ex-ante and site monitoring and survey
Programming activities for building recovery and transformation
Master plan conception (project of external areas and landmarks)
Design of the adaptive reuse intervention (hypothesis of building refurbishment and conversion actions)
A
A1
A2
A3
A4
A5
A6
A7
A8
B
B1
B3
C
C1
C2
C4
D
D1
D2
D3
D4
D5
E
E1
E2
E3
F
F1
F3
F4
F5
G
G1
G2
G3
G4
H
H1
H2
H3

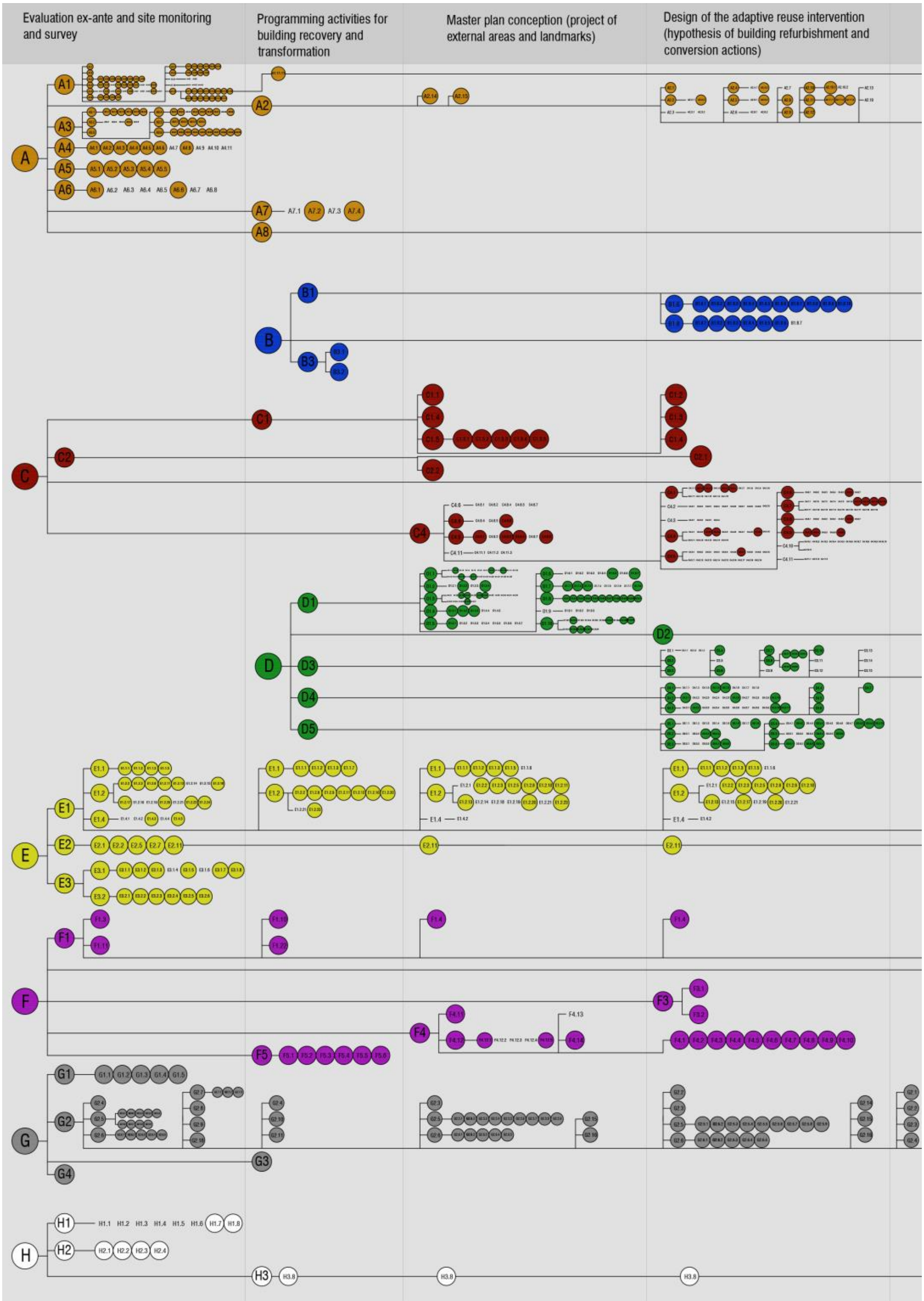

Plan approval
Implementation of recovery and reuse interventions on the existing structure and realisation of new buildings
Evaluation of building quality (safety and security) and community spatial usability
Evaluation ex-post and maintenance activities
Partial scores
9.08
6.60
7.91
9.99
10.47
8.92
6.97
Total score
59.94
40.43
B2
C3
F2
F1.8
F1.9
E1.1
E1.2
E1.3
E1.4
E1.5
E1.6
E2.3
E2.4
E2.5
E2.6
E2.7
E2.8
E2.9
E2.10
H3.2 H3.3 H3.9
H3.1 H3.3 H3.4 H3.5 H3.6 H3.10
H3.7 H3.11
H3.4 H3.5

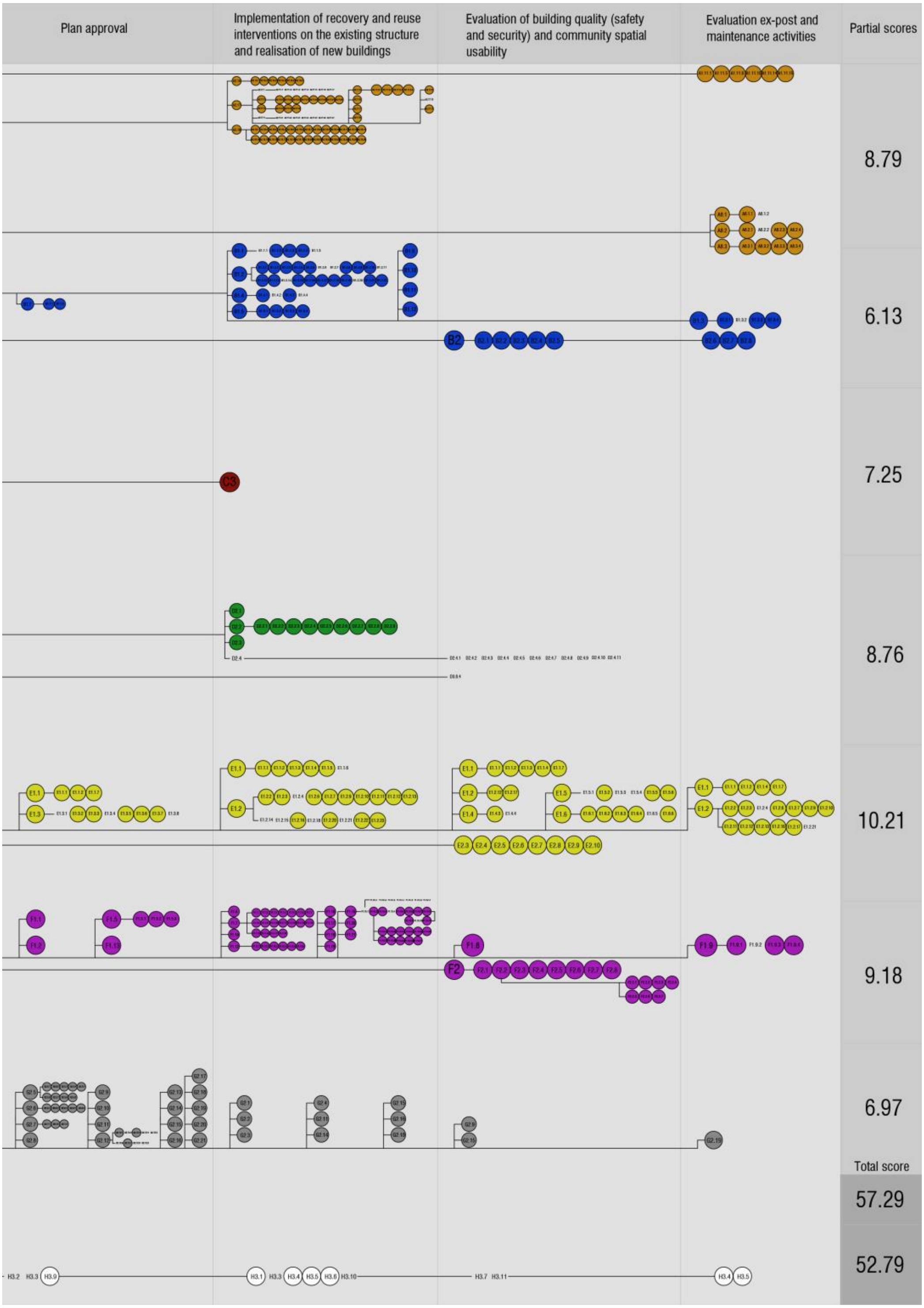

Evaluation ex-ante and site monitoring and survey
Programming activities for building recovery and transformation
Master plan conception (project of external areas and landmarks)
Design of the adaptive reuse intervention (hypothesis of building refurbishment and conversion actions)
A
A1
A2
A3
A4
A5
A6
A7
A8
B
B1
B3
C
C1
C2
C4
D
D1
D2
D3
D4
D5
E
E1
E2
E3
F
F1
F3
F4
F5
G
G1
G2
G3
G4
H
H1
H2
H3


Plan approval
Implementation of recovery and reuse interventions on the existing structure and realisation of new buildings
Evaluation of building quality (safety and security) and community spatial usability
Evaluation ex-post and maintenance activities
Partial scores
7.65
5.60
6.26
9.83
9.81
8.28
7.77
Total score
55.20
25.24
B2
C3
F2
H3.2 H3.3 H3.9
H3.1 H3.3 H3.4 H3.5 H3.6 H3.10
H3.7 H3.11
H3.4 H3.5


Evaluation ex-ante and site monitoring and survey
Programming activities for building recovery and transformation
Master plan conception (project of external areas and landmarks)
Design of the adaptive reuse intervention (hypothesis of building refurbishment and conversion actions)
A
A1
A2
A3
A4
A5
A6
A7
A8
B
B1
B3
C
C1
C2
C4
D
D1
D2
D3
D4
D5
E
E1
E2
E3
F
F1
F3
F4
F5
G
G1
G2
G3
G4
H
H1
H2
H3


Plan approval
Implementation of recovery and reuse interventions on the existing structure and realisation of new buildings
Evaluation of building quality (safety and security) and community spatial usability
Evaluation ex-post and maintenance activities
Partial scores
9.01
6.92
8.61
9.02
9.76
9.32
7.84
Total score
60.48
49.93


Evaluation ex-ante and site monitoring and survey
Programming activities for building recovery and transformation
Master plan conception (project of external areas and landmarks)
Design of the adaptive reuse intervention (hypothesis of building refurbishment and conversion actions)
A
A1
A2
A3
A4
A5
A6
A7
A8
B
B1
B3
C
C1
C2
C4
D
D1
D2
D3
D4
D5
E
E1
E2
E3
F
F1
F3
F4
F5
G
G1
G2
G3
G4
H
H1
H2
H3


Plan approval
Implementation of recovery and reuse interventions on the existing structure and realisation of new buildings
Evaluation of building quality (safety and security) and community spatial usability
Evaluation ex-post and maintenance activities
Partial scores
8.79
6.13
7.25
8.76
10.21
9.18
6.97
Total score
57.29
52.79

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ACRONYMS

AHP	Analytic Hierarchy Process
AIPAI	Italian Association for Industrial Archaeological Heritage (Associazione Italiana per il Patrimonio Archeologico Industriale)
AM	Adaptive Management
ANCE	National Association of Building Constructors (Associazione Nazionale Costruttori Edili)
ANP	Analytic Network Process
APPEA	Landscaped and Ecologically Equipped Production Area (Area Produttiva Paesaggisticamente ed Ecologicamente Attrezzata)
ARP Model	Adaptive Reuse Potential Model
ASI	Industrial Development Area (Area di Sviluppo Industriale)
AUDIS	Association of Abandoned Urban Areas (Associazione Aree Urbane Dismesse)
BIM	Building Information Modeling
CI	Consistency Index
CR	Consistency Ratio
CTF	Chemistry and Pharmaceutical Technologies (Chimica e Tecnologie Farmaceutiche)
DCS	Design Criteria System
DEMATEL	Decision-Making Trial and Evaluation Laboratory
Do.Co.Mo.Mo	International Committee for Documentation and Conservation of buildings, sites and neighbourhoods of the Modern Movement

DPP	Preliminary Programmatic Document (Documento Programmatico Preliminare)
DRAG	Regional Planning Document (Documento Regionale di Assetto Generale)
DSS	Decision Support System
DSSs	Decision Support Systems
e. c.	Evaluation coefficients
E-FAITH	European Federation of Associations for Industrial Heritage and Technical Heritage
ENEL	National Electricity Board (Ente Nazionale per l'Energia Elettrica)
GDP	Gross Domestic Product
ICCROM	The International Centre for Conservation and the Roma Center
ICOMOS	International Council on Monuments and Sites
ID Code	Identity Code
ISTAT	National Statistical Institute (Istituto Nazionale di Statistica)
IT	Information Technology
LCA	Life-Cycle Assessment
MADA	Multi-Attribute Decision Analysis
MAVT	Multi-Attribute Value Theory
MCDM	Multi-Criteria Decision-Making
MCDMA	Multi-Criteria Decision-Making Analyses
MP	Mathematical Programming
NTA	Technical Implementing Standards (Norme Tecniche di Attuazione)
O-AHP	Optimised Analytic Hierarchy Process
PPTR	Regional Territorial Landscape Plan (Piano Paesaggistico Territoriale Regionale)
PROMETHEE	Preference Ranking Organisation Method for Enrichment Evaluations
PUG	General Urban Plan (Piano Urbanistico Generale)
RI	Random Index
SDGs	Sustainable Development Goals

SPGE	Pugliese General Electricity Company (Società Generale Pugliese di Elettricità)
STEPS	Herbal sciences and technologies and health products (Scienze e Tecnologie Erboristiche e dei Prodotti per la Salute)
SWOT	Strengths, Weaknesses, Opportunities and Threats
TICCIH	The International Committee for the Conservation of the Industrial Heritage
UNESCO	United Nations Educational, Scientific and Cultural Organisation
VARM Model	Virtual Adaptive Reuse Multicriteria Model

LIST OF FIGURES

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- Carovigno waterfront re-development project _ Carovigno
- Re-development project of the San Cataldo lighthouse _ Bari
- Bari South Coast International Competition _ Bari
- Urban regeneration process – ARU 10 _ Fasano
- Trevi – L'opera d'arte nell'opera d'arte _ Trevi
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ACADEMIC ACTIVITIES

• Period	From 10/2020
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• Period	From 11/2017 to 02/2018
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PUBLICATIONS

Vizzarri, C., Fatiguso, F., 2019. A multicriteria model description for the refurbishment of abandoned industries. 2019 IEEE International Conference on Systems, Man and Cybernetics (SMC), October 2019, Bari, Italy, pp. 970-975.

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CONFERENCES

International Conference EICTUS 2019 – University of Strasbourg – From 26/06/2019 to 28/06/2019.

National Conference Colloqui.AT.e 2019 – Politecnico di Torino – From 25/09/2019 to 28/09/2019.

International Conference IEEE SMC 2019 – Sheraton Hotel Bari – From 07/10/2019 to 09/10/2019.

International Conference REHABEND 2020 – University of Granada and University of Cantabria – From 25/09/2020 to 27/09/2020 (online conference).

National Conference Colloqui.AT.e 2020 – Università di Catania – 10/12/2020 (online conference).

INTERNATIONAL COMPETITIONS

- Piscina Mirabilis/Bacoli _ Re-use Italy _ 2020.
- Barjeel Museum for Modern Arab Art _ Rifat Chadirji Prize _ 2019.
- Peace Pavilion _ Kaira Looro Competition _ 2019.
- Re-use the castle/Ripafratta _ Re-use Italy _ 2019.
- Art Prison _ Young Architects Competition _ 2018.

HONORS AND AWARDS

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PERSONAL SKILLS

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Bari, 15/01/2021

Signature