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Development of a Decision Support System for the structural degradation analysis of RC buildings supported by user-reported data and modern Information Technologies

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	Abstract Exposure to aggressive environmental agents and aging can seriously harm reinforced concrete (RC) structures and affect the building's service life. In particular, many buildings built during the extensive dissemination of RC construction technique present criticalities regarding performance and durability due to many issues: inadequate design of technical details, incorrect execution method, inadequate materials, improper maintenance or intrinsic limits and vulnerability of concrete. Consequently, management and monitoring of existing buildings is a complex issue for holders and administrators that are responsible for the building operability and user safety. On the other hand, large-scale degradation analysis and maintenance procedures present critical points: i) non-uniform building knowledge, ii) need of performing several inspections, iii) complexity of the diagnostics related to the subjectivity of the surveyor, iv) vastness and deployment of buildings in the region. Such issues become particularly complex for public or private administrators, who usually have limited resources and often cannot rely methodologies and tools to face the problem. This thesis proposes an innovative approach for detecting building criticalities. In order to achieve the new system, four synergistically related methods are suitably developed and listed as follows: i) a novel DSS methodology for buildings' assessment supported by modern Internet of Things tools (smart devices) and Information Technologies; ii) an innovative Optimized AHP (O-AHP) based on a Mathematical Programming problem; iii) a calibration procedure based on the Tuutti model to consider the damage evolution of reinforcements' corrosion and tune the KPIs; iv) a Test Site involving 131 building on the Valencian coasts to test the DSS. In particular, the proposed DSS includes an innovative software application (APP) implemented on mobile devices and a web service-based Quality Detection Platform (QDP) that stores and processes data. The APP allows the building users to report criticalities through photographic acquisition and to answer a specific questionnaire. Collected data are processed by the QDP, which quantifies critical issues through the set of key performance indices (KPIs). The DSS allows monitoring buildings at the regional scale and provides a classification of the most damaged buildings, which is useful for civil protection aims and for the prioritization of interventions.		2018	D.R.R.S Doctor of Philosophy in Risk and Environmental, Territorial and Building Development Coordinator: Prof. Michele Mossa XXXI CYCLE ICAR/09 – Structural engineering ICAR/10 – Building design DICATECh Department of Civil, Environmental, Building Engineering and Chemistry	Valentino Sangiorgio Development of a Decision Support System for the structural degradation analysis of RC buildings supported by user-reported data and modern Information Technologies Prof. Giuseppina Uva Prof. Jose M. Adam DICATECh - Politecnico di Bari ICITECH - Universitat Politècnica de València Prof. Fabio Fatiguso Prof. Humberto Varum DICATECh - Politecnico di Bari FEUP - Universidade do Porto	2018
			07			



D.R.R.S.

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Coordinator: Prof. Michele Mossa

XXXI CYCLE

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Department of Civil, Environmental,
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POLITECNICO DI BARI

07

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Development of a Decision Support System for the structural degradation analysis of RC buildings supported by user-reported data and modern Information Technologies

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Development of a Decision Support System for the structural degradation analysis of RC buildings supported by user-reported data and modern Information Technologies

Progettazione di un Sistema di Supporto alle Decisioni per l'analisi del degrado strutturale supportato da approcci di user-reporting e da moderne tecnologie dell'informazione

EXTENDED ABSTRACT (eng)

Exposure to aggressive environmental agents and aging can seriously harm reinforced concrete (RC) structures and affect the building's service life. In particular, many buildings built during the extensive dissemination of RC construction technique present criticalities regarding performance and durability due to many issues: inadequate design of technical details, incorrect execution method, inadequate materials, improper maintenance, intrinsic limits and vulnerability of concrete.

Consequently, management and monitoring of existing buildings is a complex issue for holders and administrators that are responsible for the building operability and user safety. Such operations can be simplified by using Decision Support Systems (DSSs) to evaluate the criticalities that can compromise human safety or building usability. In this field, analysis of degradation level has been extensively and fruitfully applied to schedule maintenance and monitoring. During such analysis, several decision making and prioritization are necessary and these are typically faced by the use of Multi Criteria Decision Making methods (MCDM) such as the Analytic Hierarchy Process (AHP), increasingly used in the construction field (Hsieh 2004).

On the other hand, large-scale degradation analysis and maintenance procedures present critical points: i) non-uniform building knowledge, ii) need of performing several inspections, iii) complexity of the diagnostics related to the subjectivity of the surveyor iv) vastness and deployment of buildings in the region. Such issues become particularly

complex for public or private administrators, who usually have limited resources and often cannot rely methodologies and tools to face the problem.

This thesis proposes an innovative approach for detecting building criticalities. In order to achieve the new system, four synergistically related methods are suitably developed and listed as follows: i) a novel DSS methodology for buildings' assessment supported by modern Internet of Things tools (smart devices) and Information Technologies. This instrument allows to perform a user-reporting based data acquisition and bring together the technicians personal experience and the huge amount of available data analyzed by the DSS; ii) an innovative Optimized AHP (O-AHP) based on a Mathematical Programming problem. Such a O-AHP is used to derive three suitable Key Performance Indicators (KPIs) devoted to the building degradation assessment; iii) a calibration procedure based on the Tuutti model to consider the damage evolution of reinforcements' corrosion and to tune the KPIs; iv) a Test Site involving 131 building on the Valencian coasts to test the DSS.

In particular, the proposed DSS includes an innovative software application (APP) implemented on mobile devices and a web service-based Quality Detection Platform (QDP) that stores and processes data. The APP allows the building users to report criticalities through photographic acquisition and to answer a specific questionnaire. Collected data are processed by the QDP, which quantifies critical issues through the set of key performance indices (KPIs). The DSS allows monitoring buildings at the regional scale and provides a classification of the most damaged buildings, which is useful for civil protection aims and for the prioritization of interventions.

A key point of the proposed method is the effective evaluation of the KPIs, which depend on a very large number of possible damages affecting the building. In this field, the use of AHP can be particular efficient but it presents great difficulties when the number of criteria or alternatives is large. To overcome such a drawback, a novel optimized-AHP (O-AHP) method is developed by redefining the weight evaluation by using a mathematical programming formulation. The validation benchmark tests have shown that the O-AHP exhibits the same effectiveness of standard AHP and can be successfully applied for complex problems.

In addition, the KPIs obtained through O-AHP, have been calibrated exploiting the well-known Tuutti model to consider the damage evolution of reinforcements' corrosion. An optimal calibration point has been identified by using a comparison with a similar approach developed in the University of Brasilia and with the results of a set of case studies performed in Italy, Portugal and Brazil.

Finally, a Test site in the Valencian coast has been developed to test the obtained DSS procedure on a large scale by surveying one hundred and thirty-one buildings exposed to an aggressive marine atmosphere.

key words

Existing Reinforced Concrete Building; Building performance; Damage assessment; Analytic Hierarchy Process (AHP); Structural condition assessment; Maintenance of Facilities; Environmental interaction; Optimization;

EXTENDED ABSTRACT (ita)

L'esposizione ad un ambiente aggressivo e l'invecchiamento possono essere causa di gravi danni per le strutture in calcestruzzo armato e compromettere la vita utile degli edifici. Molte strutture costruite durante la diffusione estensiva del calcestruzzo armato presentano diverse criticità riguardanti le caratteristiche prestazionali e la durabilità a causa di diverse problematiche: inadeguata progettazione della struttura e dei dettagli costruttivi, incorretta fase di esecuzione, materiali inadeguati, manutenzione inadeguata e vulnerabilità intrinseca del calcestruzzo.

Di conseguenza, il monitoraggio e la gestione degli edifici esistenti è un problema complesso per gli amministratori responsabili della funzionalità delle costruzioni e della sicurezza degli utenti. Queste operazioni possono essere semplificate da Sistemi di Supporto alle Decisioni (DSSs) per la valutazione dei danni che compromettono le prestazioni e la sicurezza dell'edificio. In questo campo l'analisi del degrado strutturale è ampiamente utilizzata per la programmazione della manutenzione e per il monitoraggio. Durante queste analisi, sempre più frequentemente nel campo delle costruzioni sorgono diversi problemi decisionali che possono essere affrontati con Multi Criteria Decision Making methods (MCDM) di cui tra i più utilizzati si distingue l'Analytic Hierarchy Process (AHP).

D'altra parte, l'applicazione su vasta scala dell'analisi del degrado strutturale per la programmazione della manutenzione presenta una serie criticità: i) non uniformità della conoscenza degli edifici; ii) necessità di effettuare numerose ispezioni; iii) complessità nella diagnostica che è affetta dalla soggettività del rilevatore; iv) vastità e distribuzione degli edifici sul territorio.

Queste criticità possono diventare molto complesse per enti pubblici o privati che spesso non si affidano a metodologie ben definite e strumenti necessari ad affrontare il problema.

Questa tesi propone un Sistema di Supporto alle Decisioni per l'analisi e la diagnostica degli edifici progettato attraverso quattro tecniche innovative appositamente sviluppate che lavorano sinergicamente: i) un nuovo DSS per l'analisi degli edifici supportato da moderne tecnologie dell'informazione e della comunicazione (ICT). Questo strumento consente di unire la vasta gamma di dati analizzabili nel DSS con l'esperienza di tecnici esperti; ii) un innovativo Optimized-AHP (O-AHP) basato sulla risoluzione di un problema di programmazione matematica. Questo O-AHP è utilizzato per ottenere tre Key Performance Indicators (KPIs) che sono lo strumento principale per analizzare il degrado degli edifici; iii) una procedura di calibrazione basata sul modello di Tuutti per considerare nei KPIs l'evoluzione del danno da ossidazione nelle armature; iv) un *Test Site* sviluppato su 131 edifici per testare la procedura.

In particolare, il DSS è composto da una applicazione software (APP) implementata su dispositivi mobili ed una web service-based Quality Detection Platform (QDP) che immagazzina e processa i dati. La APP permette agli utenti degli edifici di segnalare eventuali criticità tramite ispezioni fotografiche e rispondendo ad un breve questionario guidato. I dati raccolti sono processati nella QDP che analizza e quantifica il danno tramite un set di KPIs. Il DSS ottenuto è uno strumento che permette il monitoraggio degli edifici su vasta scala fornendo una classificazione degli edifici più danneggiati, utile per gli scopi della protezione civile e per la priorità degli interventi.

Un punto chiave della metodologia proposta riguarda la definizione e calcolo dei KPIs che devono essere in grado di valutare una vasta gamma di possibili tipologie di danni. L'uso dell'AHP è particolarmente efficace in questo campo ma presenta delle criticità quando il numero dei parametri da analizzare diventa elevato. Al fine di superare questo limite del metodo classico, in questa tesi si è sviluppato un nuovo AHP Ottimizzato (O-AHP) che ridefinisce la fase del calcolo dei pesi impostando un problema di programmazione matematica. Un test di validazione mostra come il nuovo metodo O-AHP ha la stessa efficacia del metodo classico ma può essere applicato a problemi complessi e con un vasto numero di parametri da analizzare. Inoltre, una volta ottenuti i KPIs con l'O-AHP è stata effettuata una calibrazione per considerare la legge che regola l'evoluzione del danno nella corrosione delle armature del calcestruzzo armato. Un punto di

calibrazione ottimale è identificato attraverso un confronto con una metodologia sviluppata nell'University of Brasilia e tramite l'analisi di diversi casi studio situati in Italia, Portogallo e Brasile.

In fine, un test site è sviluppato sulla costa di Valencia (Spain) per testare il DSS su vasta scala, attraverso l'analisi del degrado di cento trentuno edifici esposti all'ambiente marino aggressivo.

key words

Edifici esistenti in calcestruzzo armato; Prestazioni degli edifici; Analisi del danno; Analytic Hierarchy Process (AHP); Valutazione delle condizioni strutturali; Manutenzione delle strutture; Interazione ambiente aggressivo; Ottimizzazione;

INDEX

1	INTRODUCTION	10
1.1	The problem of structural degradation of existing buildings	10
1.2	State of the art	12
1.2.1	Degradation analysis	12
1.2.2	DSS and Key Performance Indicators in building construction	14
1.2.3	Analytic Hierarchy Process in building construction	15
1.3	Research objectives	17
2	PROPOSAL OF A NOVEL USER-REPORTING BASED DECISION SUPPORT SYSTEM FOR BUILDINGS' ASSESSMENT	20
2.1	The architecture of the DSS	20
2.2	The Data Acquisition Phase	23
2.2.1	Registry Data Acquisition	23
2.2.2	Mobile Application for Regional-Scale User Reporting	25
2.3	The Data Processing Phase	26
2.4	The Diagnostics Phase	28
2.5	Definition of the DSS's Key Performance Indices: Condition Ratings	31
3	AN OPTIMIZED AHP METHODOLOGY TO PERFORM WEIGHT CALCULATION IN DSS	35
3.1	The standard AHP	36
3.2	Consistency Requirement Issues	39
3.3	The proposed Optimized Procedure for Weight Evaluation	39
3.3.1	O-AHP phase 1: Rough Ranking Evaluation of the Alternatives	42
3.3.2	O-AHP phase 2: Estimation of the Judgment Ranges	42
3.3.3	O-AHP phase 3 Mathematical Formulation	43
3.4	Validation benchmark tests	45
4	APPLICATION OF OPTIMIZED-AHP TO ASSESS THE STRUCTURAL DEGRADATION ASSESSMENT OF R.C. BUILDINGS	51
4.1	Derivation of tabulated weights with the Optimized-AHP	51
4.2	Procedure for calculating the Condition Ratings of the DSS	59
4.3	Application example of the Condition Ratings	61

5	CALIBRATION OF KEY PERFORMANCE INDICATORS THROUGH TUUTTI MODEL AND COMPARISON WITH THE METHODOLOGY “GDE-UNB”	68
5.1	The GDE-UnB Methodology: “Degree of Element Deterioration” (GDE-UNB)	68
5.2	Comparison of general aspects	71
5.3	Comparison through case studies	72
5.4	Sensitivity analysis	75
5.5	Calibration of the DSS KPIs through Tuutti model	79
5.6	Identification of the best calibration point for DSS KPIs	80
5.7	Results of the case studies	83
6	TEST SITE: LARGE-SCALE APPLICATION OF THE DSS	85
6.1	The coast of Valencia	85
6.2	Data acquisition on the Valencia coast	86
6.3	Analysis of building degradation on the Valencia coast	88
7	DISCUSSION AND RESULTS	96
7.1	The specific case of the safety of user in RC school building	96
7.1.1	Sensitivity Analysis	100
7.1.2	Diagnostic Tabs	102
7.2	The Alert-Ed Information System and APP	103
7.3	Application of the DSS to obtain the index of marine exposure	109
7.3.1	First AHP step: definition of criteria, subcriteria and intensity ranges	110
7.3.2	Second AHP step: evaluation of weights	113
7.3.3	Third AHP step: definition of marine exposure index	116
7.3.4	Calibration by an optimization procedure and sensitivity analysis using Condition Ratings	116
7.3.5	Example of application of the index of marine exposure	119
8	<i>CONCLUSIONS</i>	121
9	<i>ACKNOWLEDGEMENTS</i>	125
10	<i>REFERENCES</i>	126

1 INTRODUCTION

The introduction focuses on different aspects related to the structural degradation analysis. First the causes of structural degradation are synthetically described. Secondly the state of the art regarding the degradation analysis, maintenance, monitoring, application of DSS and Analytic Hierarchy Process in the building field is discussed. Third, the research objectives are presented.

1.1 The problem of structural degradation of existing buildings

The building system is exposed, during its life, to a physiological decline process of the performance levels. Reinforced Concrete Buildings characterize the constructive European heritage of the past 50 years and are spread throughout the Countries even in small towns. According to the geographical location and to the construction period, it can be assumed that the design is made in compliance with building standards in force at the time (Moradi-Marani et al. 2009). European RC codes have been radically changed during time. The increase of knowledge on the materials and other critical construction issues helped to improve codes and guidelines. Therefore, several specifications have been introduced in order to achieve good performance of RC. The most important requirements included over the years are the following: anti-seismic structural design; specific technical details; minimum concrete strength; quality and dosage of the concrete; quality control execution process; size of the aggregates; type of cement and the degree of compaction.

Typically, the design and construction criteria of the past do not consider a number of key principles to ensure the building durability: as a result, there are many inadequacies and weaknesses in the existing buildings particularly in the conceptual designs and in the inadequate construction details (CEN 2005, Khaghanpour et al. 2016).

In particular, the critical issues about the constructive process of the past years can be classified in three fundamental causes (Sangiorgio et al. 2016b): i) insufficient conceptual design, due to inadequate design and technical detail to ensure anti seismic

behavior and durability; ii) human negligence, and the consequent defective realization determined by insufficient control of materials and inappropriate components placement; iii) vulnerability of concrete, due to the limits of the material.

Table 1. Critical construction issues of reinforced concrete buildings

<i>Insufficient conceptual design</i>		<i>Human negligence</i>		<i>Improper maintenance</i>	<i>Vulnerability of concrete</i>
<i>Anti-seismic structural design</i>	<i>Technical details</i>	<i>Inadequate materials</i>	<i>Incorrect execution method</i>	<i>Lack of maintenance</i>	<i>Physiological event</i>
Structural complexity	Confinement of the stirrups	Cement	Improper mix water-concrete	Scheduled maintenance	Micro cracking
Asymmetrical and irregularity configuration	Longitudinal rebars	Aggregates	Insufficient vibration	Predictive Maintenance	Aggressive environmental agent
Unidirectional resistance and stiffness	Inadequate foundation	Chemical and Mineral admixtures	Modification in the construction site	Corrective maintenance	
Absence of capacity design	Insufficient connections				
Weak of soft storey	Inadequate thickness of concrete cover				
Absence of seismic joint					
Short columns					

The problems related to *Insufficient conceptual design* can be related to two main aspects: anti seismic structural design and technical details. With regard to the *Human negligence* and vulnerability of concrete, two types of human negligence may occur, the first type, inadequate materials, is related to the choice and control of materials, the second type is related to incorrect execution method (Table 1). Another cause of criticality in existing buildings is caused by *Improper maintenance*, in several cases not only a scheduling of maintenance is missing but also an appropriate intervention when damages occurs.

It should be noted that for RC residential building exposed to aggressive environments, a service life of 40-50 years (ordinary durability) may not be achieved when one of more of the following recommended actions is not performed. A final criticality refers to the *Vulnerability of concrete*, that is present even if the RC structures are well designed and workmanlike built.

Consequently, the obsolete reinforced concrete building heritage is a problem for many European regions due to the considered construction issues. A large number of buildings require intervention and specific maintenance strategy to improve the performance and safety level. These interventions are often carried out at local level and when failures occur without carrying out extensive monitoring and analysis of the buildings in worst condition on the territory.

1.2 State of the art

1.2.1 Degradation analysis

In the last few years the technical and scientific community has studied new methods to improve management and maintenance by simplifying the visual inspection activities (Rodrigues et al. 2011) through standard check lists and mobile devices applications (Sadi et al. 2014). Such systems are designed to identify materials, malfunctions, state of conservation and other component interactions (Straub 2009, Jones and Sharp 2007). The building performance analysis, with the specific focus to the issue of degradation analysis and condition assessment, is very helpful to plan maintenance and management on existing buildings. In the field of Civil Engineering, there are several applications of these analyses by using synthetic Key Performance Indices (KPIs) to quantify the degradation, named *Condition Ratings* (Straub, 2009). In several countries, the degradation analysis of buildings is performed on the basis of the diagnosis of all the single damages of the building's elements through preset compilation forms. Some assessment methods are now statutorily prescribed, and the development processes are very similar in various countries even if there are some differences in the final goal, as emphasized in the literature review of the work of Branco Pedro (2008). In particular, the condition of a building is assessed by simple and systematic decomposition of the problem into its basic components. Any defect detected in a component is assessed on a scale based on pre-defined criteria. The assessment is carried out by means of visual inspections performed by qualified surveyors. The severity level of the damages

in the different elements is registered in a checklist and then aggregated with a formula to generate a numerical score (Hovde and Moser, 2004).

The different formulas used for the aggregation of the surveyed damages are distinguished in *weighted averages*, typically used when the diagnostic is supported by Multi-Criteria Decision-Making (MCDM) and *factorial formulation*. This last one is primarily used in service life prediction promoted in the Architectural Institute of Japan (Gakkai, 1993) as well as in the subsequent regulations on service life planning of International Organization for Standardization (ISO) 15686 Part 1 (2000). The most recent research studies exploit and apply these formulations in synergy with modern expert systems for quantifying degradation (de Freitas and Delgado 2013) and predicting the residual service life of the building (Ibáñez et al. 2016, Grussing et al. 2016). A widespread method based on the *factorial formula* is the Degree of Element Deterioration developed in University of Brasilia (GDE-UnB) for the analysis of R.C. structures. The GDE-UnB formulas are based on the basic theory of “armor corrosion evolution” developed by Tuutti (1982). Such Tuutti model calibration allows considering, in the calculation, the real evolution of reinforcement corrosion. In particular, two linear steps are defined in Tuutti theory: i) the penetration of deleterious substances (carbonation and / or penetration of chlorides); ii) the propagation involving active corrosion and an unacceptable level of deterioration. In the last few years, the GDE/UnB has been extensively and fruitfully applied in South America for the degradation evaluation of R.C. buildings (Souza 2011) and bridges (Pintan et al. 2015). The original method has been subsequently modified by Lopes (1998), Boldo (2002) and Fonseca (2010) to improve the applicability to more pathologies and to improve the calculation formulas. In addition, GDE-UnB helps personal experience of technicians to establish priorities for the actions required to restore the design service life, minimizing the cost of interventions.

1.2.2 DSS and Key Performance Indicators in building construction

An effective possibility to bring together the personal experience and the huge amount of available data is offered by Decision Support Systems (*DSSs*) (Sangiorgio et al. 2018a, Brandt and Rasmussen, 2002, Lombillo 2016). A *DSS* can be defined as an interactive computer-based system, which helps decision makers to utilize data and models to solve unstructured problems (Sangiorgio et al. 2018b). In addition, the *DSS* represents a considerable powerful tool for the use of “benchmarking” in maintenance and provides a prioritization of the necessary interventions (Carnero 2014, Sangiorgio et al. 2016a, 2017a). The benchmarking achievement needs a centralized damage database and a scoring system based on a set of KPIs and *weighted averages* formulas (Ifran Che-Ani et al. 2011). Such KPIs can be obtained by exploiting Multi-Criteria Decision-Making (MCDM) (Formisano et al. 2015a, 2017) to quantify the risk connected to each criticality and the impact on the overall building safety by using weighted averages (Das and Chew 2011, Talon et al. 2008, Øien et al. 2011). The application of *DSS* and benchmarking approach can be employed in many construction fields. In particular, the methods to quantify damages are applied to evaluate risks from aging (Ellingwood 2005), hurricanes, earthquake (Maio et al. 2015) and in general from natural hazard (Vicente et al. 2011, Vicente et al. 2005, Park et al. 2003, Unnikrishnan and Barbato 2016). By using KPIs, stakeholders can identify intervention strategies considering also cost-benefit analysis issues (Ghosn et al. 2016, Li 2010).

An interesting application of *DSS* regards the maintenance and management of existing building at a regional-scale (Formisano et al. 2015b, Sangiorgio et al. 2016a) in order perform an extensive monitoring of buildings’ safety, even in the absence of scheduled maintenance, but reducing at the same time resources. On the other hand, large-scale maintenance and monitoring procedures present critical points such as incompleteness, non-uniformity of knowledge and necessity of expensive inspection and monitoring. Such issues are very complex for those public or private administrators that possess limited resources and do not have well-defined methodologies and tools to effectively address surveys and interventions at the regional-scale. In the related literature, different approaches are present that use code and protocol guidelines to extensively

assess existing buildings' criticalities (Mahli et al. 2012, Brandt et al. 2002). Such approaches are based on a semeiotic assessment, by the analysis of damages recognized through visual surveys, which is particularly effective to perform a fast screening of damaged buildings (Yadollahi et al. 2012, Castro 1994).

1.2.3 Analytic Hierarchy Process in building construction

DSSs often integrate Multi Criteria Decision Methods (MCDM) to set the analysis of damages through useful analytical approach (Schöttle and Arroyo 2016). Such approaches allow to analyze every criterion involved in the considered phenomena by exploiting KPIs to achieve a final ranking. Among the MCDM, the Analytic Hierarchy Process (AHP) is particular effective to analyze complex problems due to the characteristic decompose of the problem into independent criteria. Such an operation allows the transformation of a multidimensional scaling problem into a one-dimensional scaling problem. Therefore, every criterion is analyzed individually to identify the related priority vectors (i.e., the weights assigned to each alternative or criterion) (Saaty and Vargas 2001). The AHP uses the principal eigenvalue method for deriving ratio scale priority vectors from positive reciprocal matrices. In particular, such matrices, called matrices of comparison or *Judgment Matrices*, are established through pairs of comparisons (Barzilai et al. 1987, Saaty and Hu 1998).

Multicriteria decision making, and in particular the AHP application, is important in *DSS* for the systematic weighting and evaluation of many factors, such as efficiency, user comfort, safety, reliability, functionality, and maintainability, to characterize the design work and the weighting of soft benefits in comparison with costs (Kwon et al. 2014, Shapira and Goldenberg 2005, Fong and Choi 2000, Kahraman et al. 2003) and environmental impact (Reza et al. 2011, Chang et al. 2007 Wong and Li 2008).

Furthermore, AHP is used to support maintenance and intervention by comparing many measures, such as multiattribute, multivariate qualitative and quantitative data (Das et al. 2010). Such performance assessments are used to evaluate different aspects of construction, such as safety evaluation and management in construction sites (Teo and Ling 2006, Dağdeviren and Yüksel 2008.), green building rating (Ali and Al Nsairat

2009, Chang et al. 2007), energetic rehabilitation (Gigliarelli et al. 2011, Wang et al. 2012), construction management (Das et al. 2009, Wu et al. 2007, Kettner and Diaz 2000), large-scale structural vulnerability analysis (Panahi et al. 2014, Aghataher et al. 2008, Uva et al. 2018, Porco et al. 2015, Sangiorgio et al. 2016a, 2016b), and criticalities identification at the seismic and volcanic vulnerability assessment (Faggiano et al. 2011, Formisano and Mazzolani 2015, Li et al. 2013).

For the AHP application in the field of construction, it is often necessary to compare a large number of criteria, and the trend is to increase the involved criteria to perform complex multi attribute analysis. The limit of the AHP, which does not allow for easy applicability in the construction sector for complex problems (Arroyo et al. 2014), derive from the consistency requirement of the judgements (checked by an inconsistency performance index CI). This requirement is necessary to assess the reliability of obtained weights (Saaty and Vargas 1984, Saaty 1990). Hence, the possibility of obtaining coherent results decreases as long as the number of factors to be analyzed increases. Mathematical and psychology studies determined that the human mind is limited to 7 ± 2 alternatives in simultaneous comparison (Saaty 1977, Miller 1994), and the reliability of the results decreases as long as the number of criteria of comparison becomes large (more than nine criteria). To this aim, it is particularly important to study methodologies that are able to improve the consistency of judgments (Li et al. 2013) by transforming an inconsistent matrix into a consistent one (Saaty 2003, Saaty and Vargas 2001, Harker and Vargas 1987). Therefore, the academic community is interested in improving the AHP applicability to the building performance evaluation by exploiting the AHP ability in simplifying complex and unstructured multicriteria decision analysis. Indeed, in building applications, the number of criteria often overcomes the maximum number that allows one to obtain coherent results.

1.3 Research objectives

The thesis main objective is developing a *Decision Support System* for monitoring and diagnostics of reinforced concrete buildings. Such DSS has to be effective even if the application context is characterized by limited information and incomplete technical specifications since data is collected with the support of user-reporting.

Within a large port-folio of buildings, it is necessary to provide a prioritization by ranking their condition and exploiting an analytical approach based on the AHP and mathematical optimization. In particular, the research goal is to specify a *DSS* able to perform the following tasks: i) acquiring information on building degradation on a regional scale by reducing on-site inspections; ii) efficiently storing data; iii) performing damage diagnostics and iv) providing an automatic classification of the most damaged buildings with a prioritization of interventions.

This ambitious objective is achieved by synergistically employing four state-of-the-art techniques: i) modern Information and Communication Technologies (ICT) applied in the building monitoring and diagnostics; ii) an optimization procedure to improve the effectiveness of the Analytic Hierarchy Processes to analyze, structure the problem and define suitable KPIs; iii) a sensitivity analysis and a calibration procedure devoted to tune the KPIs; iv) a *Test Site* involving 131 buildings to test the procedure.

The *DSS* architecture includes an application software (APP) implemented on mobile devices that is connected with a Quality Detection Platform (QDP) in which data are processed and decision are suggested. The users of building can download the APP on their smart devices and contribute to the reporting by a photographic inspection of any criticality of the structure where they work or live. While acquiring the photographic data, the users are helped by a guided questionnaire in order to complete the collected information. These visual-based surveys are processed in the QDP by a procedure that categorizes the building pathologies and quantify the buildings' damages through a scoring system based on a set of KPIs, named *Condition Ratings*. This scoring system

is able to automatically perform the damages quantification thanks to tabulated weights specially developed. The achievement of *Condition Ratings* is crucial to perform diagnostics in the DSS and the analysis of the complex problem of buildings damages evaluation requires advanced techniques. An optimized Optimized-Analytic Hierarchy Processes (O-AHP) (Sangiorgio et al. 2017b) is proposed to address the problem complexity and to obtain reliable tabulated weights. The developed methodology overcomes the standard AHP drawbacks by revising the AHP weights evaluation procedure. A Mathematical Programming formulation is exploited to minimize the incoherence of the results.

The *DSS* exploits the KPIs computed by the O-AHP and provides information concerning the building damages and the ranking of the buildings that are in worst condition. The main novelty of this work is fourfold. For the first time different techniques are simultaneously employed in a structured and synergic way for specify a *DSS* methodology to analyzing the degradation of RC building structures. The resulting methodology required a variety of interdisciplinary skills, including structural engineering, forensic engineering, statistics, optimization and multi-criteria analysis. The second novel issue is the proposal of an application of the modern Internet of Things tools (smart devices) and Information Technologies allows improving and simplifying the monitoring of building at the regional scale by the *DSS* approach.

Thirdly suitable KPIs for RC structure damages are defined and calculated on the basis of an optimized AHP approach. The research has reached the ambitious result of calibrating the KPIs through the well-known Tuutti model to consider the damage evolution of reinforcements' corrosion and by performing a Sensitivity Analysis to verify the robustness of the obtained KPIs. Finally, a *Test Site* is developed to test the procedure by surveying close to two thousand buildings exposed to an aggressive marine atmosphere that can seriously harm reinforced concrete (RC) structures. In particular, many buildings close to the sea present heavy damages, mainly due to the effects of chloride.

It is worth noting that once the KPIs for RC structure damages are defined the procedure can be applied to different typologies of RC buildings, by maintaining the same

effectiveness. In order to show this peculiarity, the buildings of the case studies and the *Test Site* are selected from different types of RC constructions and different environmental conditions. In particular, the proposed method is applied to analyze small two-storey buildings little exposed to aggressive agents and multi-storey buildings near to the coast and highly exposed to the marine atmosphere.

The Thesis is organized as follows.

Section II describes the general framework and the main phases of the user-reporting based decision support system.

Section III specifies the Optimized AHP methodology to analyze complex problems.

Section IV faces the complex problem of the structural degradation assessment of R.C. buildings by applying the O-AHP in order to calculate tabulated weight of KPIs.

Section V describes the calibration of the DSS Key Performance Indicators.

Section VI exhibits a *Test Site* in the Valencian coast in order assess large-scale DSS applicability.

Section VII shows the versatility of the proposed methodology that can be used by practitioners, such as architects, engineers, and interested stakeholders, to improve management and maintenance and prioritize interventions. In particular, the DSS is applied to two different fields:

- the monitoring of school buildings to analyze the level of user safety
- the research objective of obtain an index to evaluate the aggressive marine exposure by carrying out complex and extended degradation analyses.

2 PROPOSAL OF A NOVEL USER-REPORTING BASED DECISION SUPPORT SYSTEM FOR BUILDINGS' ASSESSMENT

2.1 The architecture of the DSS

This section describes the general framework, methodology and components of the proposed *DSS* for the structural degradation analysis of the building. In particular, the system is based on three fundamental phases: i) a large-scale *Data Acquisition Phase*, which is supported by a user-reporting process; ii) a *Data Processing Phase*, which is based on suitable automatic damage classification, iii) and the *Diagnostics Phase* performed through suitable KPIs. In addition, Fig. 1 schematically shows the main phases of the proposed methodology and the tools used to reach the described objectives.

The *Data Acquisition Phase* regards the methodological approach aimed at obtaining relevant information about the examined buildings. This is performed by two issues: i) a registry data acquisition realized by *Registry Tabs*; ii) a large-scale visual survey obtained by photographic inspection performed by the users of the building through a mobile application (hereinafter, the “APP”). The APP allows the acquisition of photographic data and additional information related to the critical physical conditions from a guided questionnaire. The role of the APP for acquisition and the automatic allocation of data into the QDP (Fig. 2) is of basic importance: this method allows overcoming the typical problems of retrieving information and systematic monitoring of a large number of buildings.

In the *Data Processing Phase*, the information collected during the data acquisition phase are processed and classified into the QDP. The photographic inspections are organized in suitable *Diagnostic Tabs*, which are a useful tool for checking KPIs and validating the users' reports. The *Diagnostic Tabs* are stored into the *Matrix of Damage* that classifies each criticality based on two parameters: the damaged building component and the type of damage.

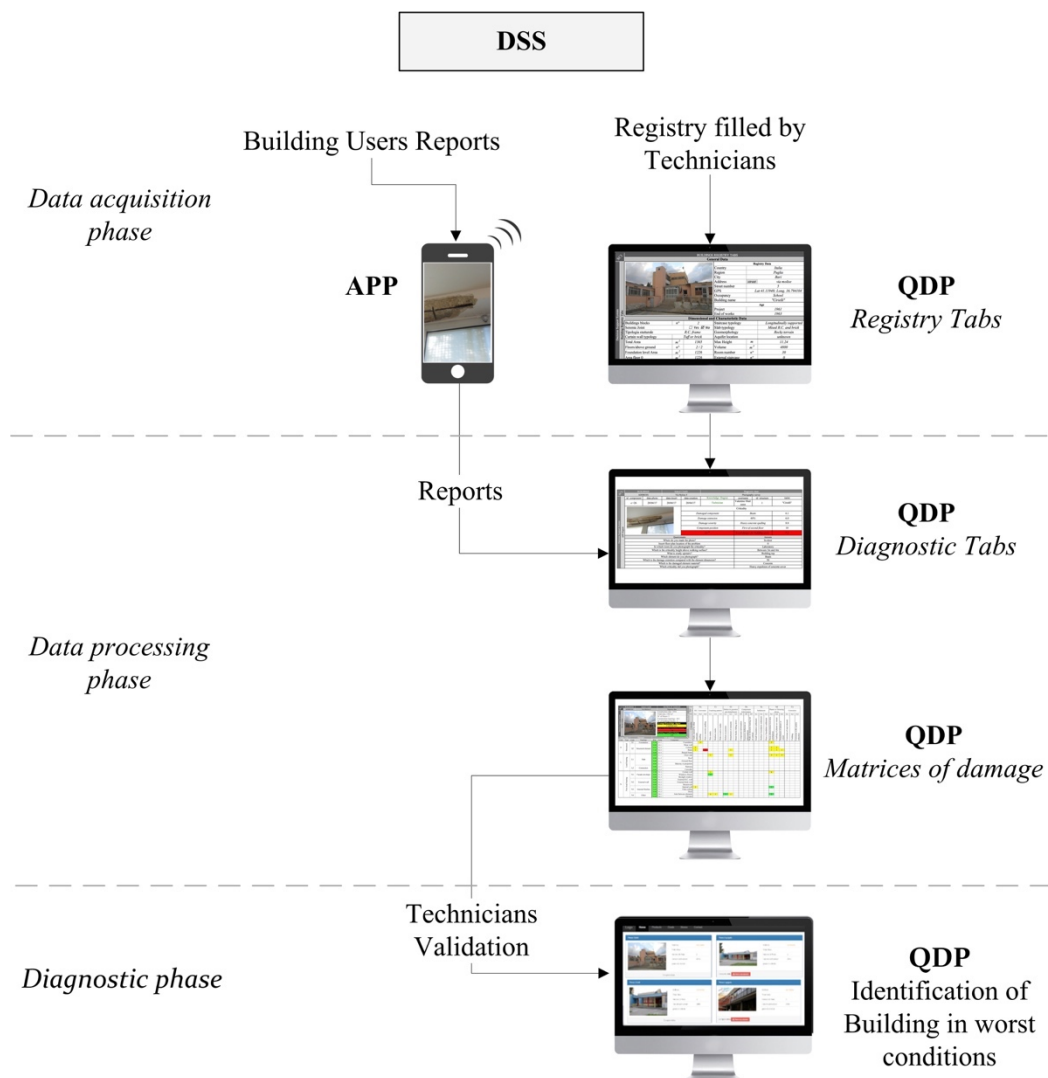


Fig. 1 – Main phases of the DSS methodology for the structural degradation analysis

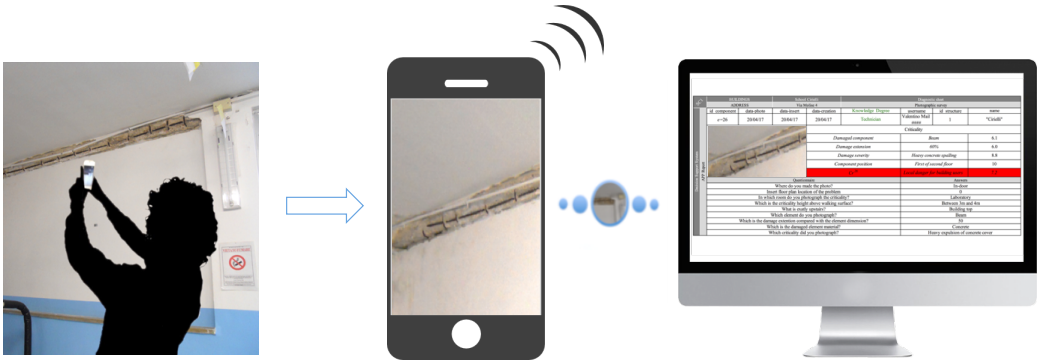


Fig. 2 - The scheme of the connection between the APP and the QDP

The *Diagnostics Phase* consists in data checking, validation, and visualization of KPIs through *Matrix of Damage* and *Diagnostic Tabs*, which synthetically allows to measure the criticalities and the relative level of risk of any single damages. In particular, this phase is devoted to support the expert *building technicians* to compares and identifies the structures that are in the worst conditions based on the computed KPIs. Moreover, thanks to the continuous updating and storage of reports, it is possible to perform a systematic monitoring of the structures.

In order to quantify and assess the damages, three KPIs, named of *Condition Ratings* and assume real values in the interval $[1, 10]$, are defined: 1) *Criticality Condition Rating* (C_r), i.e., a numerical value that qualifies a single criticality; 2) *Component Condition Rating* (CC_r), i.e., a numerical value that quantifies the critical condition of a class of components (for instance, the beams); 3) *Building Condition Rating* (BC_r), i.e., a numerical value that quantifies the global damage of the building. These three *Condition Ratings* synergistically provide additional information not obtainable from each single indicator. For instance, it is possible to detect whether the building presents few but serious damages in some components, or on the contrary whether many slight damages are widespread throughout the whole building.

2.2 The Data Acquisition Phase

2.2.1 Registry Data Acquisition

The technical registry data provide information to describe the geometric, morphological and constructive features of the building, including design prescriptions, reference building codes, and possible constructive details. The goal of this module of the *DSS* is to retrieve, process and easily store all existing information and make it available in subsequent analyses.

In particular, the Building Registry Tab (Fig.3) includes descriptive information useful to the following purposes: geographically locate each building and identify the urban context (for example, urbanistic rules and constraints); define the design code requirements at the time of construction; characterize functional and service performance. Such tab is divided into six subsections: i) general and registry data, containing information to locate the building and year of construction; ii) geometric data and constructive type, iii) availability of original projects, including source address, iv) information about later interventions and modifications, v) later vulnerability assessments, vi) reference technical codes. These data represent the basic knowledge of investigated buildings.

SC1		BUILDINGS REGISTRY TAB			
		General Data			
Decision Support System Building Registry Tabs		Registry Data			
		Country	Italy		
		Region	Puglia		
		City	Bari		
		Address	street	via molise	
		Street number	5		
		GPS	Lat 41.11948; Long. 16.794104		
		Occupancy	School		
		Building name	"Cirielli"		
		Age			
	Project	1961			
	End of works	1963			
	Geometric data and constructive type				
	Buildings blocks	n°	2	Staircase typology	Longitudinally supported
	Seismic Joint	☐ Yes ☒ No		Slab typology	Mixed R.C. and brick
	Structural typology	R.C. frame		Geomorphology	Rocky terrain
	Curtain wall typology	Tuff or brick		Aquifer location	unknown
	Total Area	m ²	1365	Max Height	m 11.24
	Floors/above ground	n°	2 / 2	Volume	m ³ 4800
	Foundation level Area	m ²	1226	Room number	n° 30
	Area floor 0	m ²	1226	External staircase	n° 0
	Area floor 1	m ²	139	Internal staircase	n° 1
	Deck area	m ²	1226	Elevator	n° 1
	Original Projects Availability				
	Preliminary Project	not available			
	Definitive Project	not available			
	Executive Project	not available			
	Interventions or modifications				
Typology	Date (year)	Description	Documentation		
☐ New floor					
☐ Internal modifications					
☐ New openings					
☐ Extensions					
☒ Elevator	2000	External elevator	Not present		
Ordinary maintenance interventions					
☐ Minor interv. on building systems					
☒ Intervention of internal finishes	2000	External doors			
Extraordinary maintenance interventions					
☐ Interventions on Internal walls					
☐ Interventions building systems					
☐ Interventions on building envelope					
☒ Elevator	2000	Solar panels installation	Not present		
Vulnerability assessments					
Typology	Date (year)	Description	Documentation		
☐ Vulnerability assessments					
☐ Vulnerability assessments					
Reference technical codes					
Typology	Date (year)	Description	Documentation		
R.D.L. 29 luglio 1993 n.682	1993	Building technical codes			

Fig. 3 - Registry Tab of Data Acquisition Phase (example of compilation school building "Cirielli, Bari,IT)

2.2.2 Mobile Application for Regional-Scale User Reporting

The APP is the second tool used for data acquisition and has been specifically developed to allow a quick visual inspection at a regional scale. The APP can be employed by the users of the building to report their visual inspection, i.e., photos and other useful information about the building's damages. It is based on two main operations: photographic shoots and compilation of a guided questionnaire. The photographic shoot enables the users to send images about the criticalities equipped with labels indicating the localization and the date of the picture. Moreover, in order to complete the description, two structured alternative questionnaires are proposed to guide the user and correctly identify additional data involved by the reported damage. The two questionnaires are calibrated for non-professional people (generic users) and people with specific competences in the field (certified users). The certified users can employ the complete questionnaire to specify important information about the damage. Moreover, it is important for large-scale acquisition that also generic users are able to report information of criticalities. To this aim, a simplified questionnaire can be used to report basic information of the surveyed issues.

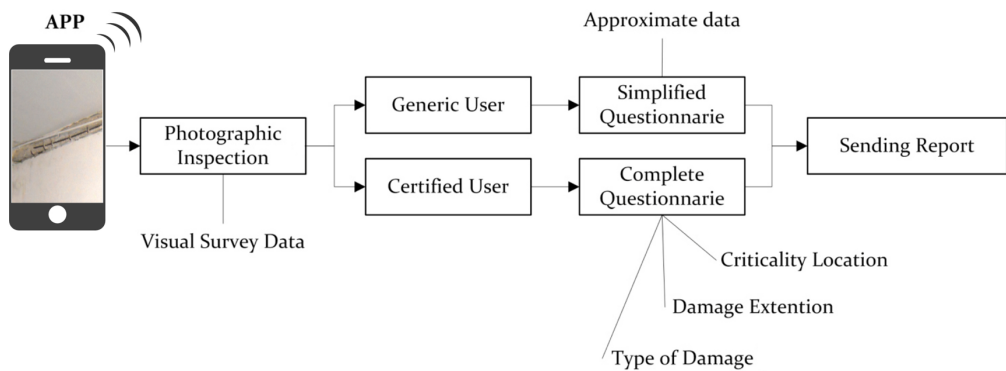


Fig. 4 - Flow chart of the steps of the App to send reports

The steps followed by the users to provide the visual inspection through the APP are schematized in Fig. 4. In the APP, the questionnaire is designed to acquire the following

information: i) the criticality location (floor, room, surrounding elements, building component and height above walking surface); ii) the extension of damage; iii) the type of damage. It is worth noting that each answer of the user opens a subsequent set of possible answers for the next step, according to a guided procedure. Fig. 5 shows an extract of the two questionnaires.

APP QUESTIONNAIRE: CERTIFIED USER

1

WHERE DO YOU MADE THE PHOTO?

Outdoor

Indoor

2

INSERT FLOOR PLAN LOCATION

Insert...

3

IN WHICH ROOM DO YOU PHOTOGRAPH THE CRITICALITY?

Office

Room

Entrance or hallway

Storeroom

....

4

WHICH IS THE CRITICALITY HEIGHT ABOVE WALKING SURFACE?

Less than 1.5m

Between 1.5m and 2m

Between 2m and 3m

Between 3m and 4m

...

5

WHAT IS EXACTLY UPSTAIRS?

Other floor

Building top

Attic

Insert other...

...

6

WHICH ELEMENT DID YOU PHOTOGRAPH?

Foundation

Column

Beam

Floor

....

7

WHICH IS THE DAMAGED ELEMENT MATERIAL?

Concrete

Wood

Steel

Glass

....

8

WHICH CRITICALITY DID YOU PHOTOGRAPH?

Rebars oxidation cracking

Spalling

Heavy concrete spalling

Component deformation

....

9

WHICH IS THE DAMAGE EXTENSION COMPARED WITH THE ELEMENT DIMENSION?

...

60%

50%

40%

....

APP QUESTIONNAIRE: GENERIC USER

1

WHERE DO YOU MADE THE PHOTO?

Outdoor

Indoor

2

INSERT FLOOR PLAN LOCATION

Insert...

3

IN WHICH ROOM DO YOU PHOTOGRAPH THE CRITICALITY?

Office

Room

Entrance or hallway

Storeroom

....

4

WHICH ELEMENT DID YOU PHOTOGRAPH?

Floor

Column

Beam

Wall

5

WHICH IS THE DAMAGED ELEMENT MATERIAL?

Concrete

Wood

Steel

Glass

6

WHICH CRITICALITY DID YOU PHOTOGRAPH?

Crack

Broken element

Wet area

Component deformation

Fig. 5 – Example of the APP questionnaire for certified users and generic user

2.3 The Data Processing Phase

The classification of criticalities detected by the APP is performed through the *Diagnostic Tabs* and the *Matrix of Damage*. The *Diagnostic Tabs* are associated to every investigated component. These tabs show the results of the questionnaire, the classification of the damage and the associated *KPI*. Such sheets allow *building technicians* to display the photographic inspections and to check, and eventually correct and validate the reported information (Fig. 29 section 4.3).

The *Matrix of Damage* synthetically displays the overall condition of each building and allows data checking and visualization of all KPIs of the structure. The classification in the matrix is set according to the type of damaged component (reported on the matrix rows) and the types of criticalities (reported on the matrix columns).

The building components classification of the *Matrix of Damage* is realized in partial compliance with the technological classification system scheme provided by the UNI 8290 (Norma, U.N.I. 8290.) Part one, to include building characteristic feature. The *Matrix of Damage* rows correspond to the type of damaged components, whereas the columns indicate the criticality types. In particular, the *Matrix of Damage* is designed by decomposing the building into three Units (structural, load bearing, not load bearing). Each Unit is divided into element typologies (for example the structural Units is divided in foundation typology and structural elements typology). In turn, the element typologies are divided into component classes (foundation, column, beam).

Secondly, the classification of the damages is set according to a well-acknowledged classification model (G. De Tommasi 2013). In this approach, the building damages are decomposed and coded on the basis of macro-types (cracking patterns, decay phenomena, etc.) and each macro-type is further classified according to the severity level of the damage. For example, the macro-type “R.C. Corrosion” is decomposed into three criticalities with increasing level of magnitude: i) *Cracks caused by rebar oxidation*, ii) *Spalling*, iii) *Heavy concrete spalling*.

-The final *Matrix of Damage* allows assessing the conditions of components and of the whole building by displaying KPIs. It should be observed that the *Matrix of Damage* is not only a methodological approach useful for data classification but provides an effective graphical user interface that quickly display an immediate overview of the building condition. In particular, for each cell of the matrix, the number of reports connected to the component and damages is displayed. The *Matrix of Damage* showed in Fig. 6 contains the defined component and damages classification for the case of the RC buildings. In such a figure, the upper left part contains a useful synthesis of inventory data, the upper right columns contain all damages classification and the relative magnitude. Additionally, lines in the inferior left part contain the ranked and coded components classification of building whereas intersection cells are predisposed the *Condition Ratings* evaluation. The data collected and processed according to these criteria allow identifying and comparing typological and constructive characteristics of the buildings.

Such a matrix creates a data base necessary for the development of condition assessment, reliability analyses and feasibility forecasts of maintenance operations.

BUILDINGS		MATRIX OF DAMAGE				Cost		Ox			Cr			Gi			Df			Se			De			Co			
Decision Support System Survey output	ADDRESS		Registry data				Building Damage Severity Criticality	Cracks caused by rebar corrosion	R.C. Corrosion			Cracking pattern			Defect in giuntion and detachment			Component deformation			Settlement			Plaster or finiscing decay			Corrosion		
	Photo (building main façade)		Total area: - m ²						Ox1	Ox2	Ox3	Cr1	Cr2	Cr3	Gi1	Gi2	Gi3	Df1	Df2	Df3	Se1	Se2	Se3	De1	De2	De3	Co1	Co2	Co3
			N° of Floors: -						Spalling	Heavy concrete spalling	Thin cracks	Medium cracks	Wide or active cracks	Defects at junction	Detachment of elements	Brick blocks falling down	Component deformation	Excessive deflection or deformations	Walls or elements leaning out or vertical	Small foundation settlement	Medium foundation settlement	Heavy foundation settlement	Decay phenomena (wet area, exfoliation)	Cracking of plaster or veneer	Detachment of plaster or veneer	Corrosion of steel element	Yielding	Corrosion with section reduction	
			Construction typology: -																										
			N° of buildings blocks: -																										
			Average Knowledge degree																										
Technical form		Substructural		Component		Foundation		Shear wall			Column		Beam		Braced frame		Floor slab		Roof		Ground floor		Balcony or projection		Staircase		Catwalks		
Code	Type	Code	Typology	Code	Component	Code	Typology	Code	Typology	Code	Typology	Code	Typology	Code	Typology	Code	Typology	Code	Typology	Code	Typology	Code	Typology	Code	Typology	Code	Typology		
S	Structural	S1	Foundation	S1.1	Foundation																								
				S2.1	Shear wall																								
		S2	Structural element	S2.2	Column																								
				S2.3	Beam																								
L	Load bearing			S2.4	Braced frame																								
		L1	Slab	L1.1	Floor slab																								
				L1.2	Roof																								
				L1.3	Ground floor																								
N	Non load bearing			L1.4	Balkony or projection																								
		L2	Connection	L2.1	Staircase																								
				L2.2	Catwalks																								
		N1	Facade envelope	N1.1	Curtain wall																								
				N1.2	Windows fixture																								
				N1.3	Skylight window																								
		N2	External wall	N2.1	External R.C. wall																								
				N2.2	External brick wall																								
N	Non load bearing			N2.3	Breastwork																								
		N3	Internal finish	N3.1	Internal wall																								
				N3.2	False ceiling																								
				N3.3	Door																								
N	Non load bearing	N4	Other	N4.1	Joint between elements																								
				N4.1	Elevator																								

Fig. 6 – Generic *Matrix of Damage*

2.4 The Diagnostics Phase

In the *Diagnostic Phase* offer the possibility to bring together the personal experience of the technicians and the huge amount of available data acquired and elaborated in the previous phases. In addition, when the methodology is applied on a large scale, a huge number of reports are provided to the QDP. Hence, the automatic classification of the damage and the automatic evaluation of the *Condition Ratings* allow technicians to perform a fast checking and validation of the acquired information. Every time a new report is added, the *Condition Ratings* are evaluated but if the system receives wrong reports or many reports for the same problem, an expert check is required. In addition, once data are checked, technicians can individuate the structures in worst condition among building investigated through the APP.

In order to better specify the connection between the phases of the DSS and explain the rules of involved actors a suitable flowchart procedure is realized in accordance with the UML framework (Fig7).

The flowchart procedure explains all the interactions between the two components of the DSS, (i.e. mobile APP and QDP), and the two actors involved in the process (i.e. *APP users* and *building technicians*). The flow is described in accordance with the three phases of the DSS: i) During the *Data Acquisition Phase* the user access to the buildings list in the QDP to select the building to survey, secondly the questionnaire is selected depending on the user profile (generic user or certified user), thirdly the user complete the questionnaire and take photographs of the damages to send the report to the QDP; ii) in the *Data Processing Phase* the QDP exploits the received reports to generate *diagnostics tabs*, furthermore the *Matrix of Damage* of the considered building is updated; iii) finally, during *Diagnostic Phase* the QDP send new damages notification to the *building staff* that can read, change or set a report as duplicate, once the checking is complete KPIs are recalculated and it is possible to compare building condition to identify priority of intervention and necessary on-site survey.

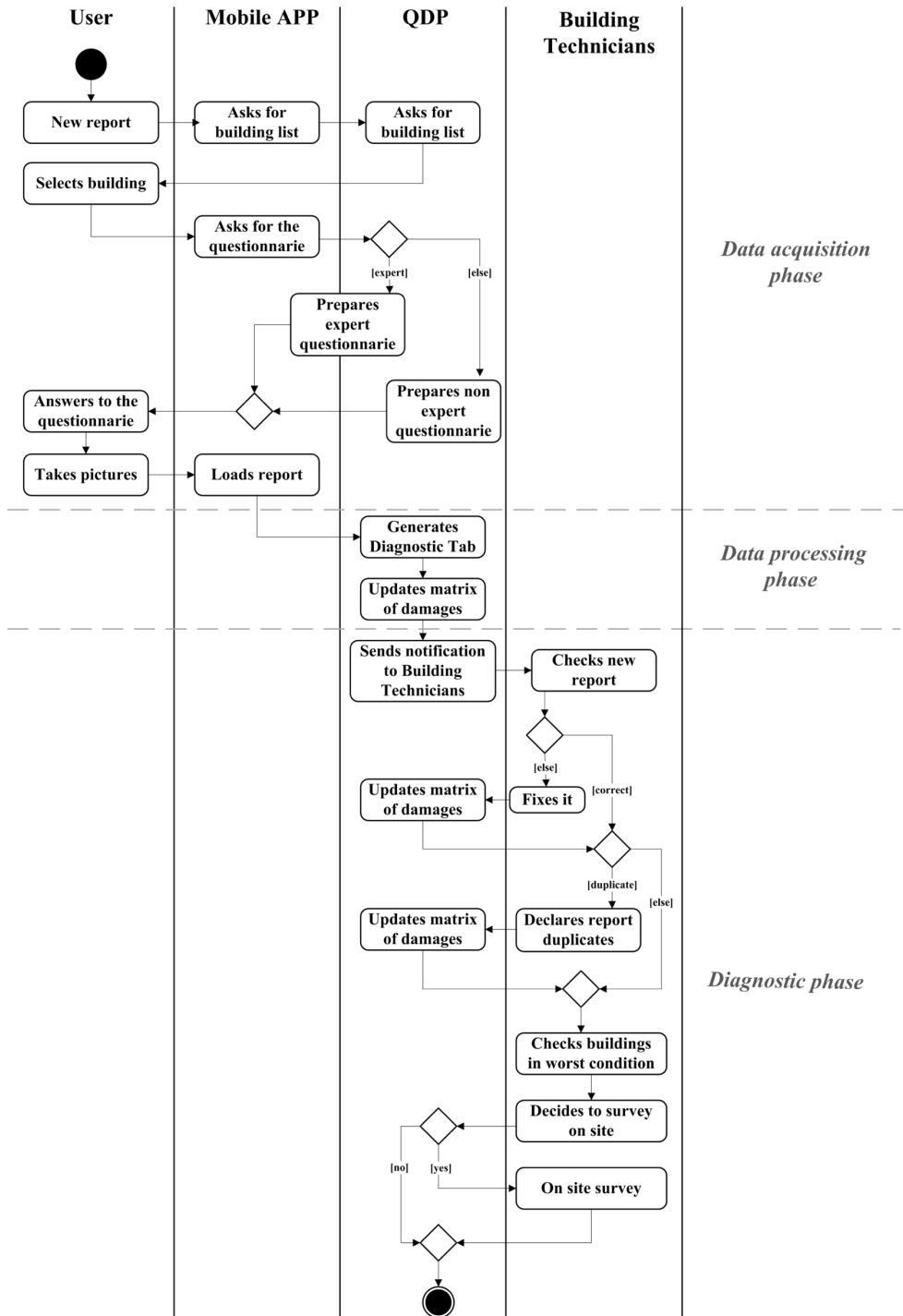


Fig. 7 – The DSS flowchart procedure described by using UML framework

The reliability of the KPIs used in the diagnostics process depend on the level of knowledge achieved for the analyzed building. The level of knowledge is related to the extension and quality of visual inspection. In the DSS, in order to categorize the level of knowledge, 3 Knowledge Degrees are defined on the basis of the experience of the User. These 3 Knowledge Degrees are described as follows: i) *Simple User*. provides the lowest knowledge level since he can only answer to the simplified questionnaire of the APP. Reported data are classified as “poor” and “approximate”; ii) *Certified User*. can answer to complete questionnaire of the APP; iii) *Technician*. is able to improve the previous levels (Simple User or Certified User) by reviewing the visual inspection through the *Diagnostic Tabs* and *Matrix of Damage*.

2.5 Definition of the DSS’s Key Performance Indices: Condition Ratings

In the DSS process, the three defined KPIs named *Condition Ratings* play a fundamental role to carry out automatic diagnostics and assessment of damaged elements. To specify the *Condition Ratings*, it is necessary to define and estimate the importance of the criteria and alternatives involved in the damage phenomena. Such evaluation can be performed through a multicriteria decision method (MCDM) [15] [16], by which numerical weights are extrapolated in order to generate a suitable tabulated value useful for the diagnostics. In particular, firstly the problem of the damage assessment is structured in criteria and alternatives, secondly an appropriate weighting is obtained by the application of the AHP, one of the most widespread MCDM, and finally the condition rating can be evaluated in the DSS by exploiting information obtained in the *Data Acquisition Phase*.

In this section the problem is specified to carry out diagnostics by obtaining three Condition Ratings. To this aim, the following sets of criteria and alternatives are defined:

$C = \{i = 1, \dots, m\}$, set of criteria of cardinality m ;

Where criterion $i = 1$ is fixed and represent the damaged building class of component, and criteria $i > 1$ are defined based on the typology of building and damages for which the DSS has to be set up.

$B_i = \{b_{ij} \mid j = 1, \dots, \alpha_i\}$, set of α_i alternatives associated to each criterion $i \in C$.

The second step is obtaining the weights, that are defined as follows:

v_i is the weight associated to criterion $i \in C$;

w_{ij} is the weight associated to alternative $b_{ij} \in B_i$ of criterion $i \in C$.

It is worth noting that the methodology to perform the crucial weight evaluation is explained and applied in the next sections. In particular a suitable optimized procedure is developed to analyze complex problems and obtain the necessary tabulated weights.

Once the weights are determined, the KPIs can be formalized to allow the automatic semeiotic assessment through the visual inspections reports. Let us assume for a building that H reports are received with the associated questionnaires. For each visual inspection h (with $h = 1, \dots, H$), the DSS assigns a set of alternatives to each criterion. Hence, it is possible to define the sets S^h (with $h = 1, \dots, H$) that collect the alternatives, denoted as b_{ij}^h , that are associated to each criterion i :

$$S^h = \{b_{ij}^h \mid b_{ij}^h \in B_i \ \forall i \in C\} \quad \text{with } h = 1, \dots, H.$$

The index associated to the *single damage* SD_h with $h = 1, \dots, H$ is obtained by the following formula (Sangiorgio et al. 2018a, 2018c):

$$SD_h = \sum_{i=1}^m v_i \times w_{ij} \quad \text{with } j \in \{1, \dots, \alpha_i\} \quad (1)$$

where for each i only one j is associated and where v_i is the weight of the i^{th} criterion and w_{ij} is the weight assigned to $b_{ij}^h \in S^h$.

Let us consider a generic component $e \in b_{1j}$ and the subset $\Delta \in H$ detected damages (inspection) related to e .

Once the single damages SD_h has been obtained, the first of the three KPIs named criticality condition rating (Cr_e), devoted to quantify the deterioration of a component, is defined as a function of the values of SD_h as follows:

$$Cr_e = SD_{max} \left(1 + \frac{\sum_{h=1}^{\Delta} SD_h - SD_{max}}{2 * \sum_{h=1}^{\Delta} SD_h} \right) \quad (2)$$

The second type of KPIs, denoted *Component Condition Rating* (CCr^k), is defined to characterize each class of damaged components after processing all collected reports. To this aim, all visual inspections are filtered by the alternatives of Criterion 1 (damaged components), extracting the following set of reports:

$$\mathcal{H}_k = \{h \mid b_{1k}^h \in S^h\} \text{ with } k = 1, \dots, \alpha_1.$$

The Component Condition Rating CCr^k is defined for each alternative of Criterion 1 ($k = 1, \dots, \alpha_1$) and quantifies the damage of a class of building components, making it possible to easily compare different buildings. To this aim, the KPI should be normalized with respect to the total number of components actually present in the building, as follows:

$$CCr^k = \frac{\sum_{h \in \mathcal{H}_k} Cr^h}{S_c^k} \quad \text{with } k = 1, \dots, \alpha_1. \quad (3)$$

Of course, the exact value S_c^k is not known at this level of analysis, but it is roughly estimated according to the following formula:

$$S_c^k = \gamma_k * S_{tot} \quad (4)$$

where S_{tot} is the building total area and γ_k is the approximated evaluation of the number of the considered components per square meter, evaluated for the specific building typology.

In order to quantify the Building Safety Performance Level due to the combinations of all pathologies, the third KPI, Building Condition Rating, is defined as follows:

$$BCr = \frac{\sum_{h=1}^H Cr^h}{S_b} . \quad (5)$$

Even in this case the exact value S_b is not known and is roughly estimated according to the following formula:

$$S_b = \gamma_b * S_{tot} . \quad (6)$$

where S_{tot} is the building total area and γ_b is the approximated evaluation of the number of all the building components per square meter for the specific building typology.

It is worth noting that the weight evaluation it is a key point for the proper operation of the DSS and the analysis of a large number of criteria and alternatives to obtain tabulated weights in the case of building diagnostics is a complex issues. To this aim next section present an Optimized version of the AHP, which allows to derive tabulated weights even if a large number of criteria and comparisons are necessary and the consistency is not easy to obtain.

3 AN OPTIMIZED AHP METHODOLOGY TO PERFORM WEIGHT CALCULATION IN DSS

The Analytic Hierarchy Process (AHP) provides the objective mathematics to process the inescapably subjective and personal opinion of an individual, the decision maker, or a group in making a decision (Saaty and Vargas 2001). The AHP is based on the decomposition of the problem into independent criteria: Such an operation allows the transformation of a multidimensional scaling analysis into a one-dimensional scaling one. Therefore, every criterion is analyzed individually to identify the related priority vectors (i.e., the weights assigned to each alternative or criterion) (Saaty and Vargas 2001). The AHP uses the principal eigenvalue method for deriving ratio scale priority vectors from positive reciprocal matrices. In particular, such matrices, called comparison matrices or *Judgment Matrices*, are established through pairs of comparisons (Barzilai et al. 1987, Saaty and Hu 1998).

To make AHP more suitable for construction field applications, the AHP weights evaluation is revised by proposing a new procedure, called Optimized AHP (O-AHP), to determine the *judgment matrix*. In particular, the limits of the human mind for simultaneous comparison are faced with defining a set of inequalities that substitute the judgment scale proposed by Saaty. In such a way, the decision maker can use just a range of judgments and focus on the main judgments instead of carrying out all of the necessary pairwise comparisons. This approach can be useful in complex problems, when the decision maker does not have a full system knowledge. In addition, a mathematical programming (MP) problem is formalized to deal with the inconsistency of the *Judgment Matrix* by minimizing the inconsistency performance index, subject to the inequalities imposed on judgments. To validate the proposed methodology, the benchmark test proposed by Whitaker (2007) is used.

3.1 The standard AHP

The proposed O-AHP methodology follows the well-known standard AHP three steps (Saaty 1980) that are specified in the following section: i) problem structuring, ii) weights evaluation, iii) summary of priorities.

Starting from a decision problem, the first step consists of structuring the problem according to a hierarchical scheme, in order to provide a detailed, simple, systematic and structured decomposition of the general problem into its basic components. To this aim, the goal of the AHP is identified and the related criteria, sub-criteria and alternatives to reach the goal are determined.

The second step of weight evaluation is the core of the method and provides the weights that are necessary for generating the ranking. More precisely, it is possible to individually analyse each aspect of the decision problem. Considering n ordered criteria of comparison (i.e., criteria, sub-criteria or alternatives in relation with criteria or sub-criteria), a $n \times n$ *Judgment Matrix* A is defined, where each upper diagonal element $a_{ij} > 0$ is generated by comparing the i -th element with the j -th one through the fundamental scale of absolute numbers. This semantic scale is composed by verbal scales that are associated to numerical values (1, 3, 5, 7, 9) and compromises (2, 4, 6, 8) between such values (Table 2) (Saaty 2008).

Table 2. Fundamental scale of absolute numbers of Saaty

Number value a_{ij}	Verbal scale	Explanation
$a_{ij} = 1$	Equal importance	Two activities contribute equally
$a_{ij} = 3$	Moderate importance of one over another	Experience and judgement slightly favour one activity over another
$a_{ij} = 5$	Strong importance	Experience and judgement strongly favour one activity over another
$a_{ij} = 7$	Very strong importance	An activity is favoured very strongly over another;
$a_{ij} = 9$	Extreme importance	An activity is favoured by at least an order of magnitude
1.5 - 4 - 6 - 8	Intermediate value	Used a compromise between two judgements
1/9, 1/8, ..., 1/2	The reciprocal number express an opposite judgement	Experience and judgement unfavour one activity over another

The inferior triangular part of the matrix is completed with the reciprocal values of the upper triangular part, by obtaining reciprocal matrix elements: $a_{ji} = \frac{1}{a_{ij}}$ or $a_{ji} \cdot a_{ij} = 1$.

Moreover, if $a_{ij} \cdot a_{jk} = a_{ik}$, then matrix A is said to be perfect consistent and its principal eigenvalue is equal to n .

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

Fig. 8. - Generic *Judgment Matrix* A

In the standard AHP, the weights are obtained by solving the following eigenvector problem:

$$A w = \lambda_{max} w \quad (7)$$

where w is the priority vector and λ_{max} is the principal eigenvalue, equal to n in a consistent matrix. When slight inconsistencies are introduced, λ_{max} differs from n (Saaty 2003).

In the AHP methodology, a *Judgment Matrix* A has to be obtained for each set of criteria, sub-criteria and alternatives that are considered in each criterion and sub-criterion. Operatively, approximate formulation methods are used in order to calculate the weights from the judgment matrix.

First, the elements of matrix A are normalized as follows:

$$x_{ij} = \frac{a_{ij}}{\sum_i a_{ij}}. \quad (8)$$

Second, the weight w_i are calculated as the average of the elements of the rows of the normalized matrix:

$$w_i = \sum_{j=1}^n \frac{x_{ij}}{n}. \quad (9)$$

At this point, it is necessary to evaluate the reliability of the obtained weights, by measuring the inconsistency of matrix A : the inconsistency increases if the judgments are badly posed. In the approximate method, the principal eigenvalue is approximately evaluated as follows (Ishizaka and Lusti 2006):

$$\lambda_{max} = \frac{1}{n} \sum_{i=1}^n \frac{a_{ij} \times w_j}{w_i}. \quad (10)$$

Now, the consistency index CI is defined according to Saaty (1980) and it increases proportionally with the inconsistency of the matrix:

$$CI = \frac{\lambda_{max} - n}{n - 1}. \quad (11)$$

In order to provide a measure of the inconsistency that is independent of the matrix order, Saaty (1980) proposed the *Consistency Ratio* (CR). This is obtained by considering the ratio between CI and its expected value (*Random Consistency Index* - RI) determined over a large number of positive reciprocal matrices of order n , whose entries are randomly chosen in the set of values $n \in \{1, 2, \dots, 10\}$

$$CR = CI/RI(n). \quad (12)$$

In this paper, in order to face a large number of alternatives, it is necessary to consider values of $RI(n)$ for $1 \leq n \leq 15$. Hence, among the different values of RI proposed in the related literature (Alonso and Lamata 2006), the values of Noble (1993) are used (Table 3).

Table 3. Random consistency index of Noble

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

On the basis of several empirical studies, Saaty (1980) concludes that the value of *Consistency Ratio* $CR < 0.10$ is acceptable. Such a test about CR is crucial for establishing the reliability of assigned judgments and it is the parameter that mathematically determines the incoherence of the decision maker judgments.

Once weight are determined, the next step of the summary of priority is performed to determine the rankings and the global weights for each alternative: to this aim the weights of each criterion and of each sub-criterion are combined with the weights of the alternatives (weights aggregation).

3.2 Consistency Requirement Issues

As already mentioned, the consistency of matrix A is required for the reliability of the assigned judgments and the relative obtained weights. It is proved that the reliability of the method is measured by the values of CR that for $n > 4$ it is $CR < 0.10$ (Saaty 2003, 1990, Saaty and Vargas 1984). Consistency ratio numerically represents the consistency of matrix A . Moreover, such consistency depends on the pairwise comparisons performed by the decision maker. As some authors remark (Li et al. 2013, Ohnishi et al. 2007), the results of AHP often lose their reliability because the matrix does not always satisfy the consistency requirement. The decision maker could improve the consistency by applying a time-consuming trial and error method and losing the focus on judgments.

3.3 The proposed Optimized Procedure for Weight Evaluation

To overcome the consistency issue of AHP for problems with a large number of criteria or alternatives, an optimized AHP methodology for generating the *Judgment Matrix* A

is proposed. In particular, the presented method focuses on the second step of AHP (i.e., the weights evaluation). The methodology can be described by considering three main O-AHP phases: i) rough ranking evaluation of the alternatives; ii) determination of a set of judgment ranges; and iii) MP formulation of the O-AHP.

In the flow chart of (Fig.9) the new methodology is schematized. Firstly, in according with the classical procedure, the problem is structured in a hierarchy of criteria, sub criteria and sets of alternatives in order to provide a detailed, simple, systematic and structured decomposition of the general problem into its basic components. Among the performed structuring of the problem criteria, sub-criteria or a set of alternatives is selected for the weighting. Subsequently operations involving the optimized procedure are performed. The first O-AHP phase is the row ranking evaluation in which it is possible to give a first classification of the elements to be weighed and eventually combine similar elements that have the same importance. In the second phase, O-AHP is applied in substitution of the standard method and the decision maker proceeds to determinate judgement ranges.

In the O-AHP phase 3, the MP problem is formulated and solved: matrix A^{Opt} and the weights w^{Opt} are provided by the MP problem solution.

Finally, if all the criteria sub-criteria and alternatives are weighted, the decision maker performs the last steps according to the classical method in which final rankings are calculated by the sum of the priorities.

In the following subsection all the O-AHP phases are described in details.

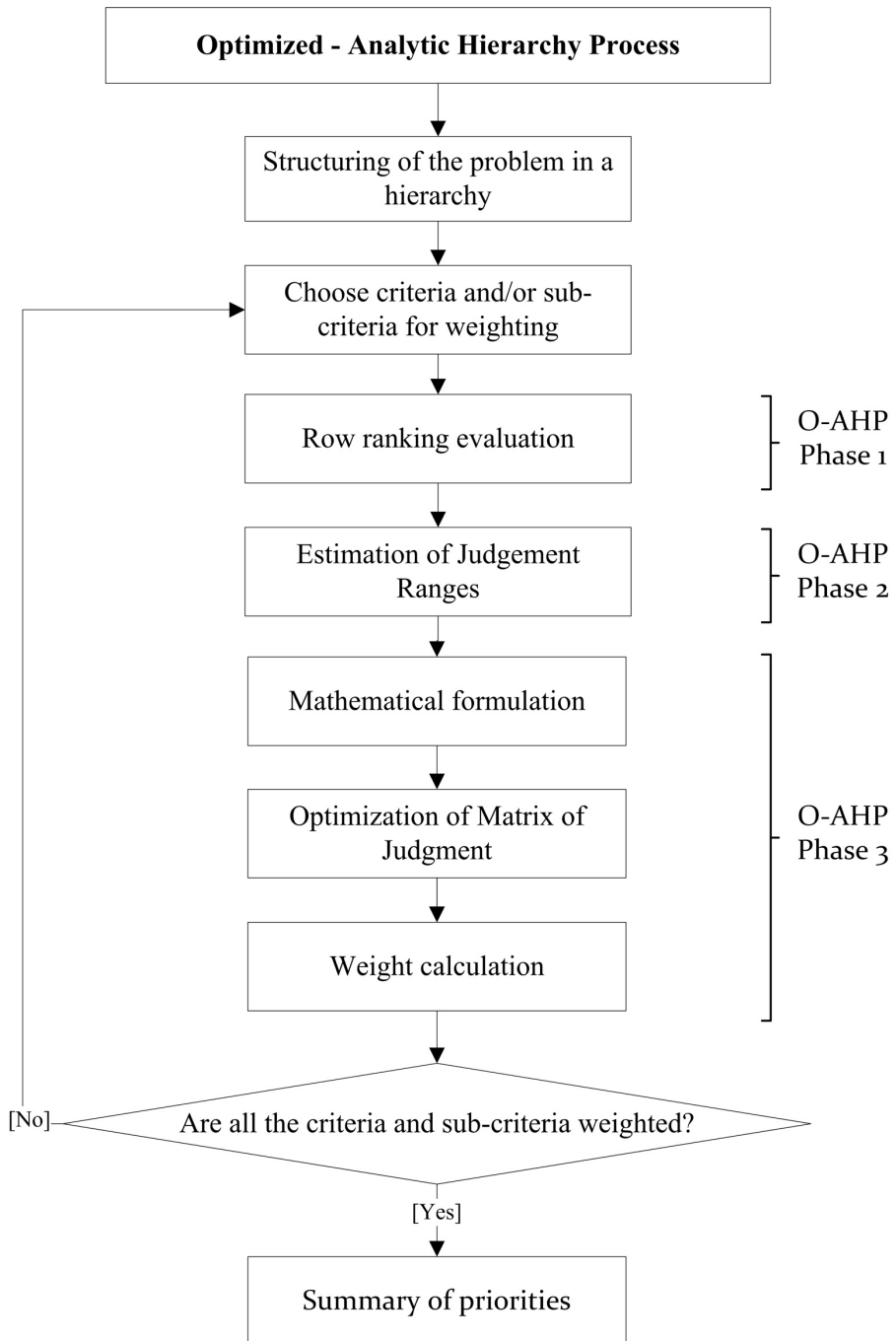


Fig. 9. - flow chart of the proposed O-AHP methodology

3.3.1 O-AHP phase 1: Rough Ranking Evaluation of the Alternatives

In some cases, it is useful to preliminarily assume an approximate ranking of the criteria of comparison. To this aim, in the Rough Ranking Evaluation *O-AHP phase 1*, criteria can be positioned starting from the first rows and columns of the *Judgment Matrix A* in descending order of importance. In addition, during such operation, it is possible to combine similar elements that have the same importance in order to reduce the alternatives. Such optional operation can simplify the subsequent steps.

3.3.2 O-AHP phase 2: Estimation of the Judgment Ranges

To consider a large number of alternatives, the decision maker can express the judgments not by single values but through the determination of ranges of values, named in this paper as “*judgment ranges*”.

In *O-AHP phase 2*, the *judgment-range* setting is formalized through inequalities, by proposing two new semantic ranges of the O-AHP, inspired by the fundamental scale of absolute numbers of Saaty: the O-AHP semantic ranges of the lower bounds (Table 4) and the O-AHP semantic ranges of the upper bounds (Table 5). Therefore, unlike the Saaty method, in which the decision maker performs the judgment by a crisp number, in the O-AHP method the decision maker expresses a judgment range (i.e., the range in which the judgment is assumed to belong).

Table 4. Optimized-AHP semantic ranges of the lower bounds

Lower bound constraint	Verbal constraint	Explanation
$a_{ij} \geq 1$	Equal or more importance, even if minimum, of i over j	A criterion is at least equally favoured
$a_{ij} \geq 2$	More importance, even if slightly, of i over j	A criterion is at least slightly favoured
$a_{ij} \geq 3$	At least moderate importance of i over j	Experience and judgement certainly favour one criteria over another
$a_{ij} \geq 5$	At least strong importance of i over j	A criterion is at least strongly favoured
$a_{ij} \geq 7$	At least very strong importance of i over j	A criterion is at least very strongly dominant
$a_{ij} \geq 9$	Max importance of i over j	A criterion is at least favoured by at least an order of magnitude
1.5 - 4 - 6 - 8	Intermediate value	Compromise between two judgements
$a_{ij} \leq (1/9, 1/8, \dots, 1)$	The reciprocal number whit the less-equal-than sign express an opposite judgement (Becomes upper bond)	Experience and judgement certainly unfavour one criteria over another

Table 5. Optimized-AHP semantic ranges of the upper bounds

Upper bound constraint	Verbal constraint	Explanation
$a_{ij} \leq 2$	The importance of i over j does not exceed the "minimum importance"	A criterion is less than slightly favoured
$a_{ij} \leq 3$	The importance of i over j does not exceed the "moderate importance"	A criterion is less than favoured
$a_{ij} \leq 5$	The importance of i over j does not exceed the "strong importance"	A criterion is less than strongly favoured
$a_{ij} \leq 7$	The importance of i over j does not exceed the "very strong importance"	A criterion is less than very strongly dominant
$a_{ij} < 9$	The importance of i over j does is not the Max importance	A criterion is less favoured by an order of magnitude
1.5 - 4 - 6 - 8	Intermediate value	Compromise between two judgements
$a_{ij} \geq (1/9, 1/8, \dots, 1/2)$	The reciprocal number the greater-than sign express an opposite judgement (Becomes lower bond)	Experience and judgement certainly unfavor one criteria over another

3.3.3 O-AHP phase 3 Mathematical Formulation

In the *O-AHP phase 3* a *MP* problem is formulated in order to determine the elements of the *Judgment Matrix A* on the basis of the inequalities assigned at the phase 2. To this aim, the sets of pairs of sub-criteria that are subject to the judgement range inequalities are defined as follows:

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

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

where K_{ij}^L and K_{ij}^U are the values assigned by the decision maker to the lower and upper bound inequalities, respectively, as detailed in Table 4 and Table 5.

Hence, it is possible to specify the entries of A by the following set $\Gamma(A)$ of mathematical constraints:

$\Gamma(A)$:

$$a_{ij} = 1 \text{ for } i, j = 1, \dots, n \text{ with } i = j \quad (13a)$$

$$1/9 < a_{ij} < 9 \text{ for } i, j = 1, \dots, n \text{ with } i < j \quad (13b)$$

$$a_{ij} \leq K_{ij}^U \quad \text{for } (i, j) \in C^U \quad (13c)$$

$$a_{ij} > K_{ij}^L \quad \text{for } (i, j) \in C^L \quad (13d)$$

$$a_{ij} = 1/a_{ji} \quad \text{for } i, j = 1, \dots, n \text{ with } i > j. \quad (13e)$$

In particular, constraints (13a), (13b) and (13e) are derived from the matrix A definition and constraints (13c) and (13d) are determined by the decision maker.

Now, in order to calculate a *Judgment Matrix* that exhibits low consistency index, the following MP problem is formulated:

$$\min CI(A) \quad (14a)$$

$$\text{subject to } \Gamma(A). \quad (14b)$$

The value of CI is calculated according to (11) and the approximated formula (10).

The MP problem solution can be found by a standard optimization solver by using the optimization toolbox of MATLAB (Mathworks 2017).

The optimized *Judgment Matrix* A^{Opt} of generic element a_{ij}^{Opt} is provided by solving the MP problem (14a-b) and consequently the optimized weights w^{Opt} is calculated.

The methodological simplifications of the proposed O-AHP are the following:

the judgments necessary to obtain the entries of A are not determined by single values of comparison but they are expressed by a set of ranges;

the consistency of matrix A is not obtained through a trial and error method as in the standard AHP, but it is optimized by the solution of the MP problem, improving the coherence of the judgments.

3.4 Validation benchmark tests

To validate the O-AHP procedure, a benchmark validation test is used, based on the methodology proposed by Saaty (2005), which is applied by Whitaker (2007) to show that the results predicted by the theory give correct answers by matching known results. The considered validation test is chosen for its relative simplicity and importance among the many that are proposed in the related literature. More precisely, the five geometric shapes shown in Fig.10 are considered and a set of individuals is asked to estimate the relative areas. In (Whitaker 2007) the actual relative values of these areas are approximately evaluated as $A = 0.47$, $B = 0.05$, $C = 0.24$, $D = 0.14$, and $E = 0.09$, where such values are normalized with respect to the overall area of the five geometric shapes.

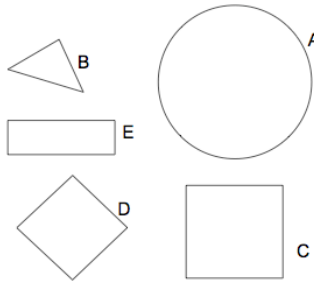


Fig. 10. - Comparison of five areas.

Moreover, the text is replicated by using the O-AHP. The mathematical constraints of Eq. (14b) are based on the judgment ranges that are evaluated by one of the decision makers, and are provided in Fig.11. The optimized *Judgment Matrix* A_{test}^{opt} is obtained by the MP Eqs. (14a) and (14b) solution, and the values of w_{test}^{opt} are determined according to Eq. (9).

Next, to compare the solutions obtained by the standard AHP, the O-AHP and the real values, the following performance index Pe is defined as

$$Pe(w) = \sum_i \frac{|w_i - rv_i|}{rv_i} \frac{1}{n} 100\% \quad (15)$$

where $w_i = i^{-th}$ component of the weight vector obtained by the standard AHP (denoted by w_{test}) or the O-AHP (denoted by w_{test}^{Opt}), rv_i are elements of vector rv associated to the real values of the geometric areas and n is the dimension of the *judgement matrix*.

Fig.12 lists, in the left side, the *judgement matrix* obtained by the MP problem solution, the values of w_{test}^{Opt} and the real values of the geometric shape areas. In addition, the right part shows the values obtained by the standard AHP provided by Whitaker (2007). Moreover, Fig. 12 reports the obtained indices $Pe(w_{test}^{Opt})$ and $Pe(w_{test})$: the outcome show that the two methodologies give the same results, both very close to the real values. The consistency of the optimized A_{test}^{Opt} is satisfied: $CR=0.0013 < 0.1$.

Moreover, the results demonstrate that all of the individuals provide a $Pe(w_{test}^{Opt})$ less than 5%. Hence, it is possible to conclude that the results obtained by the O-AHP can give accurate results as the standard AHP.

i^{th} element	K_{ij}^L	a_{ij}	K_{ij}^U	j^{th} element
A	9.0	$\leq a_{1,2} \leq$	9.0	B
A	2.5	$\leq a_{1,3} \leq$	3.0	C
A	2.0	$\leq a_{1,4} \leq$	6.0	D
A	4.0	$\leq a_{1,5} \leq$	8.0	E
B	1/6	$\leq a_{2,3} \leq$	1/5	C
B	1/4	$\leq a_{2,4} \leq$	1/3	D
B	1/2	$\leq a_{2,5} \leq$	1/1.5	E
C	1.6	$\leq a_{3,4} \leq$	1.8	D
C	1.0	$\leq a_{3,5} \leq$	3.0	E
D	1.0	$\leq a_{4,5} \leq$	2.0	E

Fig. 11. - Judgment ranges for the validation test.

A^{Opt}_{test}	A	B	C	D	E	w^{Opt}_{test}	rv	$Pe(w^{Opt}_{test})$	w_{test}	$Pe(w_{test})$	CR
A	1.0	9.0	2.5	3.4	6.0	0.498	0.470	4.8%	0.488	4.7%	0.0013
B	0.1	1.0	0.2	0.3	0.6	0.049	0.050		0.049		
C	0.4	5.0	1.0	1.6	2.7	0.225	0.240		0.233		
D	0.3	3.0	0.6	1.0	1.7	0.144	0.140		0.148		
E	0.2	1.7	0.4	0.6	1.0	0.083	0.090		0.082		

Fig. 12. - Validation benchmark test results.

Because the most significant advantage of the proposed methodology is providing reliable results also with a large number of comparisons, an additional validation test is performed considering 12 geometric shapes. Fig. 13 shows the different shapes that are chosen to repeat the test with the same set of individuals that in this case determine 66 *judgment ranges*. To simplify the judgment assignment, in this complex case it is useful to preliminarily perform a rough ranking of the shapes as listed in Fig.14. The judgment ranges used for the formalization of the optimization are reported in Fig 14.

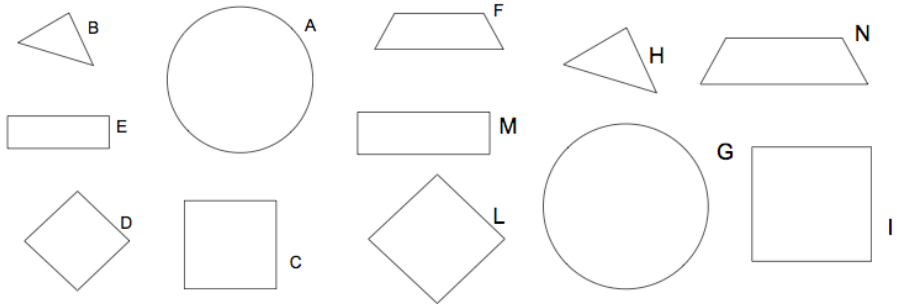


Fig. 13. - Comparison of twelve areas.

The left part of Fig. 15 lists the judgement matrix $A^{Opt}_{test,2}$ and the optimized values of $w^{Opt}_{test,2}$ obtained by solving (14a-b). In addition, the right side lists the real values of the geometric shapes areas and the average percentage error of the results, in comparison with the real value of the geometric shape. The results point out that the O-AHP weights

are very close to the real values with an average percentage error $Pe(w_{test,2}^{Opt})=2.4\%$ and the consistency test is satisfied: $CR=0.0004 < 0.1$.

All of the consulted decision makers obtain a result subject to an average percentage error less than 5%.

In conclusion, the considered test involving a large number of judgments confirms that the O-AHP exhibits the same effectiveness than in the first benchmark test. Furthermore, the methodology of O-AHP allows omitting some judgment ranges when the decision maker is not able to assign all of the ranges. Then, the decision makers are asked to progressively remove the uncertain judgment ranges. Hence, 30 constraints are removed: $a_{1,7}$ $a_{1,8}$ $a_{1,9}$ $a_{1,10}$ $a_{1,11}$ $a_{2,6}$ $a_{2,7}$ $a_{2,8}$ $a_{2,9}$ $a_{2,10}$ $a_{3,9}$ $a_{3,10}$ $a_{3,11}$ $a_{4,7}$ $a_{4,8}$ $a_{4,9}$ $a_{4,11}$ $a_{4,12}$ $a_{5,9}$ $a_{5,10}$ $a_{5,11}$ $a_{5,12}$ $a_{6,10}$ $a_{6,11}$ $a_{6,12}$ $a_{7,10}$ $a_{7,11}$ $a_{7,12}$ $a_{8,10}$ $a_{8,12}$. Also in this case, the resulting weights are very close to the real values, and the average percentage error $Pe(w_{test,2}^{Opt})$ becomes worst cases of 7%.

$i^{th} elem.$	K_{ij}^L	a_{ij}	K_{ij}^U	$j^{th} element$	$i^{th} element$	K_{ij}^L	a_{ij}	K_{ij}^U	$j^{th} element$
G	1.2	$\leq a_{1,2}$	≤ 1.5	A	L	1.5	$\leq a_{4,8}$	≤ 2.0	D
G	1.0	$\leq a_{1,3}$	≤ 2.0	I	L	2.0	$\leq a_{4,9}$	≤ 4.0	F
G	2.0	$\leq a_{1,4}$	≤ 3.0	L	L	2.0	$\leq a_{4,10}$	≤ 3.0	E
G	2.0	$\leq a_{1,5}$	≤ 3.0	C	L	3.0	$\leq a_{4,11}$	≤ 5.0	H
G	3.0	$\leq a_{1,6}$	≤ 4.0	N	L	4.0	$\leq a_{4,12}$	≤ 6.0	B
G	3.0	$\leq a_{1,7}$	≤ 4.0	M	C	1.0	$\leq a_{5,6}$	≤ 1.5	N
G	4.0	$\leq a_{1,8}$	≤ 4.0	D	C	1.0	$\leq a_{5,7}$	≤ 1.5	M
G	5.0	$\leq a_{1,9}$	≤ 7.0	F	C	1.5	$\leq a_{5,8}$	≤ 2.0	D
G	6.0	$\leq a_{1,10}$	≤ 8.0	E	C	2.0	$\leq a_{5,9}$	≤ 3.0	F
G	7.0	$\leq a_{1,11}$	≤ 8.0	H	C	2.0	$\leq a_{5,10}$	≤ 3.0	E
G	9.0	$\leq a_{1,12}$	≤ 9.0	B	C	3.0	$\leq a_{5,11}$	≤ 4.0	H
A	1.0	$\leq a_{2,3}$	≤ 1.0	I	N	4.0	$\leq a_{5,12}$	≤ 6.0	B
A	1.5	$\leq a_{2,4}$	≤ 3.0	L	N	1.2	$\leq a_{6,7}$	≤ 1.5	M
A	2.0	$\leq a_{2,5}$	≤ 2.0	C	N	1.0	$\leq a_{6,8}$	≤ 1.5	D
A	2.0	$\leq a_{2,6}$	≤ 3.0	N	N	1.5	$\leq a_{6,9}$	≤ 2.0	F
A	3.0	$\leq a_{2,7}$	≤ 4.0	M	N	2.0	$\leq a_{6,10}$	≤ 2.0	E
A	3.0	$\leq a_{2,8}$	≤ 5.0	D	N	2.5	$\leq a_{6,11}$	≤ 3.0	H
A	2.0	$\leq a_{2,9}$	≤ 4.0	F	N	3.0	$\leq a_{6,12}$	≤ 4.0	B
A	5.0	$\leq a_{2,10}$	≤ 6.0	E	M	1.0	$\leq a_{7,8}$	≤ 1.5	D
A	6.0	$\leq a_{2,11}$	≤ 7.0	H	M	1.0	$\leq a_{7,9}$	≤ 2.0	F
A	8.0	$\leq a_{2,12}$	≤ 9.0	B	M	1.5	$\leq a_{7,10}$	≤ 2.0	E
I	1.5	$\leq a_{3,4}$	≤ 2.0	L	M	1.5	$\leq a_{7,11}$	≤ 3.0	H
I	2.0	$\leq a_{3,5}$	≤ 2.0	C	M	1.0	$\leq a_{7,12}$	≤ 3.0	B
I	2.0	$\leq a_{3,6}$	≤ 3.0	N	D	1.2	$\leq a_{8,9}$	≤ 1.5	F
I	2.0	$\leq a_{3,7}$	≤ 4.0	M	D	1.5	$\leq a_{8,10}$	≤ 2.0	E
I	3.0	$\leq a_{3,8}$	≤ 4.0	D	D	2.0	$\leq a_{8,11}$	≤ 2.0	H
I	4.0	$\leq a_{3,9}$	≤ 5.0	F	D	2.0	$\leq a_{8,12}$	≤ 3.0	B
I	4.0	$\leq a_{3,10}$	≤ 6.0	E	F	1.0	$\leq a_{9,10}$	≤ 1.5	E
I	6.0	$\leq a_{3,11}$	≤ 8.0	H	F	1.5	$\leq a_{9,11}$	≤ 2.0	H
I	7.0	$\leq a_{3,12}$	≤ 8.0	B	F	1.5	$\leq a_{9,12}$	≤ 2.0	B
L	1.0	$\leq a_{4,5}$	≤ 1.5	C	E	1.0	$\leq a_{10,11}$	≤ 1.5	H
L	1.0	$\leq a_{4,6}$	≤ 1.5	N	E	1.5	$\leq a_{10,12}$	≤ 2.0	B
L	1.5	$\leq a_{4,7}$	≤ 1.5	M	H	1.0	$\leq a_{11,12}$	≤ 1.5	B

Fig. 14. - Judgment ranges for the validation test 2.

$A_{test,2}^{Opt}$	G	A	I	L	C	N	M	D	F	E	H	B	$w_{test,2}^{Opt}$	rv	$Pe(w_{test,2}^{Opt})$	CR
G	1.0	1.3	1.2	2.3	2.5	3.2	3.6	4.0	5.7	6.8	7.7	9.0	0.206	0.208	2.4%	0.0004
A	0.8	1.0	1.0	1.9	2.0	2.5	3.1	3.3	3.9	5.4	6.6	8.5	0.167	0.167		
I	0.8	1.0	1.0	1.8	2.0	2.5	2.9	3.4	4.4	5.1	6.9	7.6	0.165	0.160		
L	0.4	0.5	0.5	1.0	1.1	1.3	1.5	1.8	2.3	2.8	3.6	4.6	0.089	0.089		
C	0.4	0.5	0.5	0.9	1.0	1.3	1.4	1.7	2.3	2.6	3.4	4.3	0.084	0.082		
N	0.3	0.4	0.4	0.8	0.8	1.0	1.2	1.3	1.8	2.0	2.7	3.4	0.067	0.066		
M	0.3	0.3	0.3	0.7	0.7	0.8	1.0	1.1	1.5	1.8	2.3	2.7	0.056	0.056		
D	0.3	0.3	0.3	0.6	0.6	0.8	0.9	1.0	1.3	1.6	2.0	2.5	0.050	0.053		
F	0.2	0.3	0.2	0.4	0.4	0.6	0.7	0.7	1.0	1.2	1.6	1.8	0.038	0.039		
E	0.1	0.2	0.2	0.4	0.4	0.5	0.6	0.6	0.8	1.0	1.3	1.6	0.032	0.033		
H	0.1	0.2	0.1	0.3	0.3	0.4	0.4	0.5	0.6	0.8	1.0	1.2	0.025	0.026		
B	0.1	0.1	0.1	0.2	0.2	0.3	0.4	0.4	0.5	0.6	0.8	1.0	0.020	0.021		

Fig. 15. - Validation benchmark test 2 results.

All data regarding the validation benchmark test obtained by applying the method on a set of individuals are showed in Attachment 1.

4 APPLICATION OF OPTIMIZED-AHP TO ASSESS THE STRUCTURAL DEGRADATION ASSESSMENT OF R.C. BUILDINGS

This section presents the proposed O-AHP methodology to formulate the automatic damage quantification by the definition and evaluation of the Condition Ratings. This work focuses on the case of R.C. buildings, even if the approach has a general validity for the assessment of existing building.

4.1 Derivation of tabulated weights with the Optimized-AHP

In this section the key point of weight evaluation is performed to make the KPIs calculation effective for the structural degradation assessment of RC buildings in the DSS. The first step of AHP consists in the Structure of the Problem of the structural degradation assessment of RC buildings. The goal is the assessment of building degradation level and the problem is structured in $m=4$ criteria: i) *Damaged component*, i.e. the importance of the damaged component; ii) *Damage extension*, i.e. the damage extension in relation with the component dimension expressed in percentage; iii) *Damage severity*, i.e. the gravity of the damage; iv) *component position*, i.e. the position of the component based on the floor in which it is located.

Fig. 16 shows the hierarchical scheme of the problem structuring. In the *damaged severity* criterion, for each type of damage, 3 increasing severity levels are defined. For example: thin cracks ($w_{3,4}$), medium cracks ($w_{3,5}$) and wide or active cracks ($w_{3,6}$) are the levels corresponding to the Cracks damage (the last 4 alternatives regard wood pathologies $w_{3,22}$ $w_{3,23}$ $w_{3,24}$ $w_{3,25}$ and indicated with * are excluded).

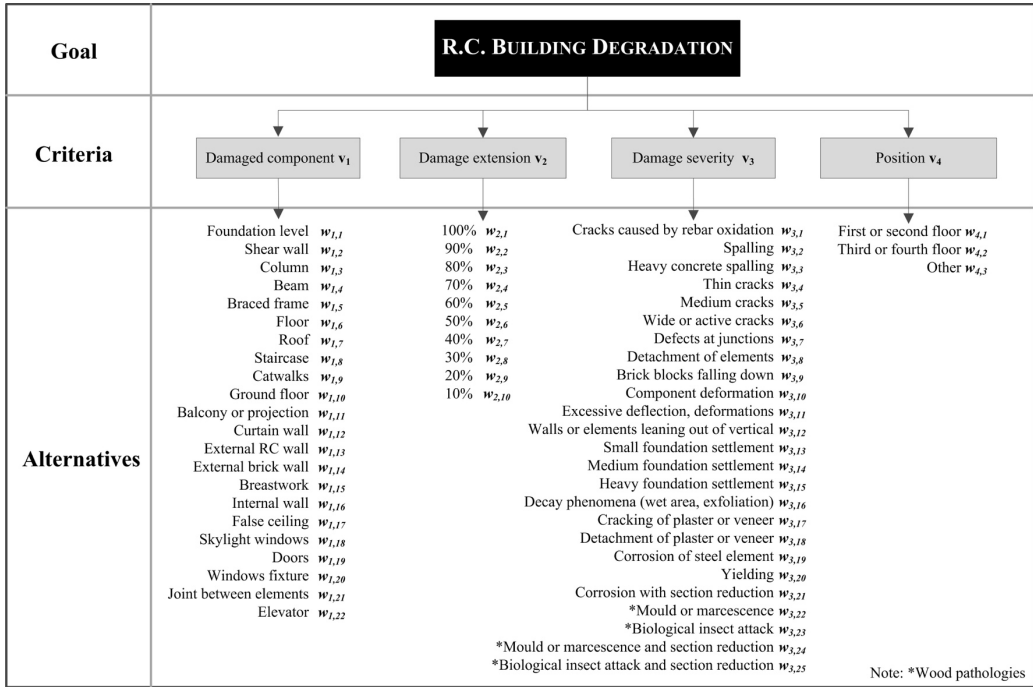


Fig. 16. - Structure of the Problem: weight criteria and alternatives to perform a assessment of RC building degradation level.

In particular the application of the *O-AHP 3 phase* is necessary for the complexity of the problem and the huge number of alternatives to obtain weights that are defined as follows:

v_i is the weight associated to each criterion $i \in C$;

w_{ij} is the weight associated to each criterion alternative $b_{ij} \in B_i$ of criterion $i \in C$.

Fig. 16 shows the association of weight v_i to the i^{th} criterion for $i=1, \dots, m$ and the weights w_{ij} to the j^{th} alternative for $j=1, \dots, \alpha_i$. In Fig. 16 it holds $m=4$, $\alpha_1=22$, $\alpha_2=10$, $\alpha_3=25$ and $\alpha_4=3$.

The O-AHP is performed by obtaining five *Judgment Matrices*: four matrices to identify the weights w_{ij} of the alternatives and one matrix to identify the weight v_i of each criterion.

In particular, starting from the *damaged component* alternatives the *O-AHP phase 1* is performed. Among the 22 alternatives similar elements are combined and a rough ranking evaluation is performed as shows in Fig. 16. In the *O-AHP phase 2*, the 66 *Judgement ranges* are assigned and showed in Fig. 17

Damaged component	$w_{1,j}$	→	Similar components are combined	$w_{1,j}$
Foundation level	$w_{1,1}$		Foundation level	$w_{1,1}$
Shear wall	$w_{1,2}$		Shear wall	$w_{1,2}$
Column	$w_{1,3}$		Column	$w_{1,3}$
Beam	$w_{1,4}$		Beam or Braced frame	$w_{1,4} \ w_{1,5}$
Braced frame	$w_{1,5}$		Slabs, Staircase or Catwalk	$w_{1,6} \ w_{1,7} \ w_{1,8} \ w_{1,9} \ w_{1,10}$
Floor	$w_{1,6}$		Balcony or projection	$w_{1,11}$
Roof	$w_{1,7}$		Curtain wall	$w_{1,12}$
Staircase	$w_{1,8}$		External walls	$w_{1,13} \ w_{1,14}$
Catwalks	$w_{1,9}$		Breastwork, Internal wall or False ceiling	$w_{1,15} \ w_{1,16} \ w_{1,17}$
Ground floor	$w_{1,10}$		Door or Window	$w_{1,18} \ w_{1,19} \ w_{1,20}$
Balcony or projection	$w_{1,11}$		Joint between elements	$w_{1,21}$
Curtain wall	$w_{1,12}$		Elevator	$w_{1,22}$
External R.C. wall	$w_{1,13}$			
External brick wall	$w_{1,14}$			
Breastwork	$w_{1,15}$			
Internal wall	$w_{1,16}$			
False ceiling	$w_{1,17}$			
Skylight window	$w_{1,18}$			
Door	$w_{1,19}$			
Windows fixture	$w_{1,20}$			
Joint between elements	$w_{1,21}$			
Elevator	$w_{1,22}$			
			Rough ranking evaluation	$w_{1,j}$
			Foundation level	$w_{1,1}$
			Shear wall	$w_{1,2}$
			Column	$w_{1,3}$
			Beam or Braced frame	$w_{1,4} \ w_{1,5}$
			Slabs, Staircase or Catwalk	$w_{1,6} \ w_{1,7} \ w_{1,8} \ w_{1,9} \ w_{1,10}$
			Balcony or projection	$w_{1,11}$
			Curtain wall	$w_{1,12}$
			External walls	$w_{1,13} \ w_{1,14}$
			Breastwork, Internal wall or False ceiling	$w_{1,15} \ w_{1,16} \ w_{1,17}$
			Door or Window	$w_{1,18} \ w_{1,19} \ w_{1,20}$
			Elevator	$w_{1,22}$
			Joint between elements	$w_{1,21}$

Fig. 16. Rough ranking evaluation for alternatives of criterion 1

i-th element	K_{ij}^L	a_{ij}	K_{ij}^U	j-th element
Foundation level (F.I.)	1.0	$\leq a_{1,2}$	≤ 1.2	Shear wall (S.w.)
Foundation level (F.I.)	1.3	$\leq a_{1,3}$	≤ 1.3	Column (C.)
Foundation level (F.I.)	1.6	$\leq a_{1,4}$	≤ 1.7	Beam or Braced frame (B.B.)
Foundation level (F.I.)	1.6	$\leq a_{1,5}$	≤ 1.7	Slabs, Staircase or Catwalk (S.S.)
Foundation level (F.I.)	1.8	$\leq a_{1,6}$	≤ 1.9	Balcony or projection (B.p.)
Foundation level (F.I.)	4.1	$\leq a_{1,7}$	≤ 4.2	Curtain wall (C.w.)
Foundation level (F.I.)	4.5	$\leq a_{1,8}$	≤ 4.6	External walls (E.w.)
Foundation level (F.I.)	5.8	$\leq a_{1,9}$	≤ 5.9	Breastwork, Internal wall or False ceiling (B.I.)
Foundation level (F.I.)	9.0	$\leq a_{1,10}$	≤ 9.0	Door or Window (D.W.)
Foundation level (F.I.)	9.0	$\leq a_{1,11}$	≤ 9.0	Elevator (E.)
Foundation level (F.I.)	9.0	$\leq a_{1,12}$	≤ 9.0	Joint between elements (J.)
Shear wall (S.w.)	1.1	$\leq a_{2,3}$	≤ 1.2	Column (C.)
Shear wall (S.w.)	1.5	$\leq a_{2,4}$	≤ 1.5	Beam or Braced frame (B.B.)
Shear wall (S.w.)	1.5	$\leq a_{2,5}$	≤ 1.5	Slabs, Staircase or Catwalk (S.S.)
Shear wall (S.w.)	1.6	$\leq a_{2,6}$	≤ 1.7	Balcony or projection (B.p.)
Shear wall (S.w.)	3.7	$\leq a_{2,7}$	≤ 3.8	Curtain wall (C.w.)
Shear wall (S.w.)	4.0	$\leq a_{2,8}$	≤ 4.2	External walls (E.w.)
Shear wall (S.w.)	5.3	$\leq a_{2,9}$	≤ 5.4	Breastwork, Internal wall or False ceiling (B.I.)
Shear wall (S.w.)	8.5	$\leq a_{2,10}$	≤ 8.5	Door or Window (D.W.)
Shear wall (S.w.)	8.5	$\leq a_{2,11}$	≤ 8.5	Elevator (E.)
Shear wall (S.w.)	8.5	$\leq a_{2,12}$	≤ 8.5	Joint between elements (J.)
Column (C.)	1.3	$\leq a_{3,4}$	≤ 1.3	Beam or Braced frame (B.B.)
Column (C.)	1.3	$\leq a_{3,5}$	≤ 1.3	Slabs, Staircase or Catwalk (S.S.)
Column (C.)	1.4	$\leq a_{3,6}$	≤ 1.5	Balcony or projection (B.p.)
Column (C.)	3.2	$\leq a_{3,7}$	≤ 3.4	Curtain wall (C.w.)
Column (C.)	3.5	$\leq a_{3,8}$	≤ 3.6	External walls (E.w.)
Column (C.)	4.5	$\leq a_{3,9}$	≤ 4.7	Breastwork, Internal wall or False ceiling (B.I.)
Column (C.)	7.8	$\leq a_{3,10}$	≤ 8.0	Door or Window (D.W.)
Column (C.)	7.8	$\leq a_{3,11}$	≤ 8.0	Elevator (E.)
Column (C.)	7.8	$\leq a_{3,12}$	≤ 8.0	Joint between elements (J.)
Beam or Braced frame (B.B.)	0.9	$\leq a_{4,5}$	≤ 1.1	Slabs, Staircase or Catwalk (S.S.)
Beam or Braced frame (B.B.)	1.0	$\leq a_{4,6}$	≤ 1.2	Balcony or projection (B.p.)
Beam or Braced frame (B.B.)	2.5	$\leq a_{4,7}$	≤ 2.6	Curtain wall (C.w.)
Beam or Braced frame (B.B.)	2.7	$\leq a_{4,8}$	≤ 2.8	External walls (E.w.)
Beam or Braced frame (B.B.)	3.5	$\leq a_{4,9}$	≤ 3.6	Breastwork, Internal wall or False ceiling (B.I.)
Beam or Braced frame (B.B.)	6.0	$\leq a_{4,10}$	≤ 6.2	Door or Window (D.W.)
Beam or Braced frame (B.B.)	6.0	$\leq a_{4,11}$	≤ 6.2	Elevator (E.)
Beam or Braced frame (B.B.)	6.0	$\leq a_{4,12}$	≤ 6.2	Joint between elements (J.)
Slabs, Staircase or Catwalk (S.S.)	1.0	$\leq a_{5,6}$	≤ 1.2	Balcony or projection (B.p.)
Slabs, Staircase or Catwalk (S.S.)	2.5	$\leq a_{5,7}$	≤ 2.6	Curtain wall (C.w.)
Slabs, Staircase or Catwalk (S.S.)	2.7	$\leq a_{5,8}$	≤ 2.8	External walls (E.w.)
Slabs, Staircase or Catwalk (S.S.)	3.5	$\leq a_{5,9}$	≤ 3.6	Breastwork, Internal wall or False ceiling (B.I.)
Slabs, Staircase or Catwalk (S.S.)	6.0	$\leq a_{5,10}$	≤ 6.2	Door or Window (D.W.)
Slabs, Staircase or Catwalk (S.S.)	6.0	$\leq a_{5,11}$	≤ 6.2	Elevator (E.)
Slabs, Staircase or Catwalk (S.S.)	6.0	$\leq a_{5,12}$	≤ 6.2	Joint between elements (J.)
Balcony or projection (B.p.)	2.2	$\leq a_{6,7}$	≤ 2.4	Curtain wall (C.w.)
Balcony or projection (B.p.)	2.4	$\leq a_{6,8}$	≤ 2.6	External walls (E.w.)
Balcony or projection (B.p.)	3.2	$\leq a_{6,9}$	≤ 3.3	Breastwork, Internal wall or False ceiling (B.I.)
Balcony or projection (B.p.)	5.4	$\leq a_{6,10}$	≤ 5.6	Door or Window (D.W.)
Balcony or projection (B.p.)	5.4	$\leq a_{6,11}$	≤ 5.6	Elevator (E.)
Balcony or projection (B.p.)	5.4	$\leq a_{6,12}$	≤ 5.6	Joint between elements (J.)
Curtain wall (C.w.)	1.1	$\leq a_{7,8}$	≤ 1.2	External walls (E.w.)
Curtain wall (C.w.)	1.4	$\leq a_{7,9}$	≤ 1.5	Breastwork, Internal wall or False ceiling (B.I.)
Curtain wall (C.w.)	2.4	$\leq a_{7,10}$	≤ 2.5	Door or Window (D.W.)
Curtain wall (C.w.)	2.4	$\leq a_{7,11}$	≤ 2.5	Elevator (E.)
Curtain wall (C.w.)	2.4	$\leq a_{7,12}$	≤ 2.5	Joint between elements (J.)
External walls (E.w.)	1.2	$\leq a_{8,9}$	≤ 1.4	Breastwork, Internal wall or False ceiling (B.I.)
External walls (E.w.)	2.1	$\leq a_{8,10}$	≤ 2.3	Door or Window (D.W.)
External walls (E.w.)	2.1	$\leq a_{8,11}$	≤ 2.3	Elevator (E.)
External walls (E.w.)	2.1	$\leq a_{8,12}$	≤ 2.3	Joint between elements (J.)
Breastwork, Internal wall or False ceiling (B.I.)	1.6	$\leq a_{9,10}$	≤ 1.8	Door or Window (D.W.)
Breastwork, Internal wall or False ceiling (B.I.)	1.6	$\leq a_{9,11}$	≤ 1.8	Elevator (E.)
Breastwork, Internal wall or False ceiling (B.I.)	1.6	$\leq a_{9,12}$	≤ 1.8	Joint between elements (J.)
Door or Window (D.W.)	1.0	$\leq a_{10,11}$	≤ 1.0	Elevator (E.)
Door or Window (D.W.)	1.0	$\leq a_{10,12}$	≤ 1.0	Joint between elements (J.)
Elevator (E.)	1.0	$\leq a_{11,12}$	≤ 1.0	Joint between elements (J.)

Fig. 17. - Judgement ranges assigned for the damaged component alternatives

The solution of the MP problem (14a-b) provides the *Judgment Matrix* and weights are derived from the solution of equation (7). Fig. 18 shows the *Judgment Matrix*, the obtained weights and the value of *CR* that satisfies the Saaty consistency requirement ($CR < 0.1$).

Damaged Component	(F.I.)	(S.w.)	(C.)	(B.B.)	(S.S.)	(B.p.)	(C.w.)	(E.w.)	(B.I.)	(D.W.)	(E.)	(J.)	$w_{I,j}$	<i>CR</i>
Foundation level (F.I.)	1.0	1.1	1.3	1.6	1.6	1.8	4.1	4.5	5.8	9.0	9.0	9.0	10.0	0.0001
Shear wall (S.w.)	0.9	1.0	1.2	1.5	1.5	1.7	3.8	4.1	5.4	9.0	9.0	9.0	9.1	
Column (C.)	0.8	0.9	1.0	1.3	1.3	1.4	3.3	3.6	4.6	7.9	7.9	7.9	7.9	
Beam or Braced frame (B.B.)	0.6	0.7	0.8	1.0	1.0	1.1	2.5	2.8	3.6	6.1	6.1	6.1	6.1	
Slabs, Staircase or Catwalk (S.S.)	0.6	0.7	0.8	1.0	1.0	1.1	2.5	2.8	3.6	6.1	6.1	6.1	6.1	
Balcony or projection (B.p.)	0.6	0.6	0.7	0.9	0.9	1.0	2.3	2.5	3.2	5.5	5.5	5.5	5.5	
Curtain wall (C.w.)	0.2	0.3	0.3	0.4	0.4	0.4	1.0	1.1	1.4	2.4	2.4	2.4	2.4	
External walls (E.w.)	0.2	0.2	0.3	0.4	0.4	0.4	0.9	1.0	1.3	2.2	2.2	2.2	2.2	
Breastwork, Internal wall or False ceiling (B.I.)	0.2	0.2	0.2	0.3	0.3	0.3	0.7	0.8	1.0	1.7	1.7	1.7	1.7	
Door or Window (D.W.)	0.1	0.1	0.1	0.2	0.2	0.2	0.4	0.5	0.6	1.0	1.0	1.0	1.0	
Elevator (E.)	0.1	0.1	0.1	0.2	0.2	0.2	0.4	0.5	0.6	1.0	1.0	1.0	1.0	
Joint between elements (J.)	0.1	0.1	0.1	0.2	0.2	0.2	0.4	0.5	0.6	1.0	1.0	1.0	1.0	

Fig. 18. - Optimized *Judgment Matrix*, Weights, and *CR* Obtained by O-AHP in *damaged component* Criterion

Following the same O-AHP procedure all the weight of the alternatives of the criterion *damaged component* are evaluated. In particular, Fig.19 shows the rough ranking evaluation, Fig. 20 shows the assigned 66 *Judgement ranges* and Fig. 21 shows the obtained *Judgment Matrix* with the derived weights and the value of *CR* that satisfies the Saaty consistency requirement ($CR < 0.1$).

Moreover, to obtain the weights of the last two sets of alternatives and to weight the criteria, the Optimization is not necessary and the *Judgment Matrices* can be obtained directly from the standard AHP procedure. Fig. 22, Fig. 23, Fig. 24 shows the *Judgment Matrix*, the derived weights and the value of *CR* that satisfies the Saaty consistency requirement ($CR < 0.1$) of *Damage extension* alternatives, *Position* alternatives and *criteria* respectively.

<i>Damaged severity</i>	<i>w_{3j}</i>		Similar damage are combined	<i>w_{3j}</i>
Cracks caused by rebar corrosion	<i>w_{3,1}</i>	→	Generic thin cracks of defects at junctions	<i>w_{3,1} w_{3,4} w_{3,7} w_{3,17}</i>
Spalling	<i>w_{3,2}</i>		Broken brick blocks and Loss of adesion and detachment	<i>w_{3,2} w_{3,8} w_{3,9} w_{3,18}</i>
Heavy concrete spalling	<i>w_{3,3}</i>		Heavy expulsion of concrete cover and rebars oxidation	<i>w_{3,3}</i>
Thin cracks	<i>w_{3,4}</i>		Medium cracs	<i>w_{3,5}</i>
Medium cracks	<i>w_{3,5}</i>		Cracks active, cracs wide or Walls leaning out of vertical	<i>w_{3,6} w_{3,12}</i>
Wide or active cracks	<i>w_{3,6}</i>		Component deformation	<i>w_{3,10}</i>
Defects at junction	<i>w_{3,7}</i>		Excessive deflection, deformations or displacements	<i>w_{3,11}</i>
Detachment of elements	<i>w_{3,8}</i>		Medium settlement or differential settlement	<i>w_{3,13} w_{3,14}</i>
Brick blocks falling down	<i>w_{3,9}</i>		Heavy foundation problem	<i>w_{3,15}</i>
Component deformation	<i>w_{3,10}</i>		Decay pheneomena	<i>w_{3,16}</i>
Excessive deflection or deformations	<i>w_{3,11}</i>		Wood or steel patology (not heavy)	<i>w_{3,19} w_{3,22} w_{3,23}</i>
Walls or elements leaning out of vertical	<i>w_{3,12}</i>		Pathology cause of section reduction	<i>w_{3,20} w_{3,21} w_{3,23} w_{3,24} w_{3,25}</i>
Small foundation settlement	<i>w_{3,13}</i>			
Medium foundation settlement	<i>w_{3,14}</i>			
Heavy foundation settlement	<i>w_{3,15}</i>			
Decay phenomena (wet area. exfoliation)	<i>w_{3,16}</i>			
Cracking of plaster or veneer	<i>w_{3,17}</i>			
Detachment of plaster or veneer	<i>w_{3,18}</i>			
Corrosion of steel element	<i>w_{3,19}</i>			
Yielding	<i>w_{3,20}</i>			
Corrosion with section reduction	<i>w_{3,21}</i>			
Mould or marcescence	<i>w_{3,22}</i>			
Biological insect attack	<i>w_{3,23}</i>			
Mould or marcescence and section reduction	<i>w_{3,24}</i>			
Biological insect attack and section reduction	<i>w_{3,25}</i>			
			Rouge ranking evaluation	<i>w_{3j}</i>
			Heavy foundation problem	<i>w_{3,15}</i>
			Cracks active, cracs wide or Walls leaning out of vertical	<i>w_{3,6} w_{3,12}</i>
			Excessive deflection, deformations or displacements	<i>w_{3,11}</i>
			Heavy expulsion of concrete cover and rebars oxidation	<i>w_{3,3}</i>
			Medium settlement or differential settlement	<i>w_{3,13} w_{3,14}</i>
			Pathology cause of section reduction	<i>w_{3,20} w_{3,21} w_{3,23} w_{3,24} w_{3,25}</i>
			Medium cracs	<i>w_{3,5}</i>
			Broken brick blocks and Loss of adesion and detachment	<i>w_{3,2} w_{3,8} w_{3,9} w_{3,18}</i>
			Component deformation	<i>w_{3,10}</i>
			Generic thin cracks of defects at junctions	<i>w_{3,1} w_{3,4} w_{3,7} w_{3,17}</i>
			Decay pheneomena	<i>w_{3,16}</i>
			Wood or steel patology (not heavy)	<i>w_{3,19} w_{3,22} w_{3,23}</i>

Fig. 19. - Rouge ranking evaluation for alternatives of criterion 3

i-th element	K_{ij}^I	a_{ij}	K_{ij}^{II}	j-th element
Heavy foundation problem (H.f.)	1.0	$a_{1,2} \leq 1.1$		Cracks active, cracs wide or Walls leaning out of vertical (C.W.)
Heavy foundation problem (H.f.)	1.1	$a_{1,3} \leq 1.2$		Excessive deflection, deformations or displacements (E.d.)
Heavy foundation problem (H.f.)	1.1	$a_{1,4} \leq 1.2$		Heavy expulsion of concrete cover and rebars oxidation (H.e.)
Heavy foundation problem (H.f.)	1.8	$a_{1,5} \leq 1.9$		Medium settlement or differential settlement (M.s.)
Heavy foundation problem (H.f.)	2.0	$a_{1,6} \leq 2.0$		Pathology cause of section reduction (P.s.)
Heavy foundation problem (H.f.)	2.1	$a_{1,7} \leq 2.3$		Medium cracs (M.c.)
Heavy foundation problem (H.f.)	2.5	$a_{1,8} \leq 2.6$		Broken brick blocks and Loss of adesion and detachment (B.b.)
Heavy foundation problem (H.f.)	2.8	$a_{1,9} \leq 2.8$		Component deformation (C.d.)
Heavy foundation problem (H.f.)	3.3	$a_{1,10} \leq 3.3$		Generic thin cracks of defects at junctions (G.t.)
Heavy foundation problem (H.f.)	5.0	$a_{1,11} \leq 6.0$		Decay phenomena (D.p.)
Heavy foundation problem (H.f.)	9.0	$a_{1,12} \leq 9.0$		Wood or steel pathology (not heavy) (W.s.)
Cracks active, cracs wide or Walls leaning out of vertical (C.W.)	1.0	$a_{2,3} \leq 1.1$		Excessive deflection, deformations or displacements (E.d.)
Cracks active, cracs wide or Walls leaning out of vertical (C.W.)	1.1	$a_{2,4} \leq 1.1$		Heavy expulsion of concrete cover and rebars oxidation (H.e.)
Cracks active, cracs wide or Walls leaning out of vertical (C.W.)	1.8	$a_{2,5} \leq 2.0$		Medium settlement or differential settlement (M.s.)
Cracks active, cracs wide or Walls leaning out of vertical (C.W.)	1.9	$a_{2,6} \leq 2.0$		Pathology cause of section reduction (P.s.)
Cracks active, cracs wide or Walls leaning out of vertical (C.W.)	2.1	$a_{2,7} \leq 2.2$		Medium cracs (M.c.)
Cracks active, cracs wide or Walls leaning out of vertical (C.W.)	2.4	$a_{2,8} \leq 2.5$		Broken brick blocks and Loss of adesion and detachment (B.b.)
Cracks active, cracs wide or Walls leaning out of vertical (C.W.)	2.7	$a_{2,9} \leq 3.0$		Component deformation (C.d.)
Cracks active, cracs wide or Walls leaning out of vertical (C.W.)	3.2	$a_{2,10} \leq 3.3$		Generic thin cracks of defects at junctions (G.t.)
Cracks active, cracs wide or Walls leaning out of vertical (C.W.)	4.5	$a_{2,11} \leq 4.8$		Decay phenomena (D.p.)
Cracks active, cracs wide or Walls leaning out of vertical (C.W.)	9.0	$a_{2,12} \leq 9.0$		Wood or steel pathology (not heavy) (W.s.)
Excessive deflection, deformations or displacements (E.d.)	1.0	$a_{3,4} \leq 1.0$		Heavy expulsion of concrete cover and rebars oxidation (H.e.)
Excessive deflection, deformations or displacements (E.d.)	1.7	$a_{3,5} \leq 1.8$		Medium settlement or differential settlement (M.s.)
Excessive deflection, deformations or displacements (E.d.)	1.8	$a_{3,6} \leq 1.9$		Pathology cause of section reduction (P.s.)
Excessive deflection, deformations or displacements (E.d.)	2.0	$a_{3,7} \leq 2.0$		Medium cracs (M.c.)
Excessive deflection, deformations or displacements (E.d.)	2.3	$a_{3,8} \leq 2.5$		Broken brick blocks and Loss of adesion and detachment (B.b.)
Excessive deflection, deformations or displacements (E.d.)	2.5	$a_{3,9} \leq 2.6$		Component deformation (C.d.)
Excessive deflection, deformations or displacements (E.d.)	3.0	$a_{3,10} \leq 3.0$		Generic thin cracks of defects at junctions (G.t.)
Excessive deflection, deformations or displacements (E.d.)	4.5	$a_{3,11} \leq 4.6$		Decay phenomena (D.p.)
Excessive deflection, deformations or displacements (E.d.)	8.5	$a_{3,12} \leq 9.0$		Wood or steel pathology (not heavy) (W.s.)
Heavy expulsion of concrete cover and rebars oxidation (H.e.)	1.6	$a_{4,5} \leq 1.8$		Medium settlement or differential settlement (M.s.)
Heavy expulsion of concrete cover and rebars oxidation (H.e.)	1.7	$a_{4,6} \leq 1.8$		Pathology cause of section reduction (P.s.)
Heavy expulsion of concrete cover and rebars oxidation (H.e.)	2.0	$a_{4,7} \leq 2.0$		Medium cracs (M.c.)
Heavy expulsion of concrete cover and rebars oxidation (H.e.)	2.2	$a_{4,8} \leq 2.3$		Broken brick blocks and Loss of adesion and detachment (B.b.)
Heavy expulsion of concrete cover and rebars oxidation (H.e.)	2.4	$a_{4,9} \leq 2.5$		Component deformation (C.d.)
Heavy expulsion of concrete cover and rebars oxidation (H.e.)	2.9	$a_{4,10} \leq 3.0$		Generic thin cracks of defects at junctions (G.t.)
Heavy expulsion of concrete cover and rebars oxidation (H.e.)	4.2	$a_{4,11} \leq 4.5$		Decay phenomena (D.p.)
Heavy expulsion of concrete cover and rebars oxidation (H.e.)	8.6	$a_{4,12} \leq 8.7$		Wood or steel pathology (not heavy) (W.s.)
Medium settlement or differential settlement (M.s.)	1.0	$a_{5,6} \leq 1.0$		Pathology cause of section reduction (P.s.)
Medium settlement or differential settlement (M.s.)	1.1	$a_{5,7} \leq 1.2$		Medium cracs (M.c.)
Medium settlement or differential settlement (M.s.)	1.3	$a_{5,8} \leq 1.3$		Broken brick blocks and Loss of adesion and detachment (B.b.)
Medium settlement or differential settlement (M.s.)	1.3	$a_{5,9} \leq 1.5$		Component deformation (C.d.)
Medium settlement or differential settlement (M.s.)	1.5	$a_{5,10} \leq 1.8$		Generic thin cracks of defects at junctions (G.t.)
Medium settlement or differential settlement (M.s.)	2.5	$a_{5,11} \leq 3.0$		Decay phenomena (D.p.)
Medium settlement or differential settlement (M.s.)	5.0	$a_{5,12} \leq 5.0$		Wood or steel pathology (not heavy) (W.s.)
Pathology cause of section reduction (P.s.)	1.1	$a_{6,7} \leq 1.1$		Medium cracs (M.c.)
Pathology cause of section reduction (P.s.)	1.2	$a_{6,8} \leq 1.3$		Broken brick blocks and Loss of adesion and detachment (B.b.)
Pathology cause of section reduction (P.s.)	1.3	$a_{6,9} \leq 1.4$		Component deformation (C.d.)
Pathology cause of section reduction (P.s.)	1.5	$a_{6,10} \leq 2.0$		Generic thin cracks of defects at junctions (G.t.)
Pathology cause of section reduction (P.s.)	2.0	$a_{6,11} \leq 2.5$		Decay phenomena (D.p.)
Pathology cause of section reduction (P.s.)	4.5	$a_{6,12} \leq 5.0$		Wood or steel pathology (not heavy) (W.s.)
Medium cracs (M.c.)	1.1	$a_{7,8} \leq 1.2$		Broken brick blocks and Loss of adesion and detachment (B.b.)
Medium cracs (M.c.)	1.2	$a_{7,9} \leq 1.3$		Component deformation (C.d.)
Medium cracs (M.c.)	1.5	$a_{7,10} \leq 1.6$		Generic thin cracks of defects at junctions (G.t.)
Medium cracs (M.c.)	2.0	$a_{7,11} \leq 2.5$		Decay phenomena (D.p.)
Medium cracs (M.c.)	4.0	$a_{7,12} \leq 5.0$		Wood or steel pathology (not heavy) (W.s.)
Broken brick blocks and Loss of adesion and detachment (B.b.)	1.1	$a_{8,9} \leq 1.1$		Component deformation (C.d.)
Broken brick blocks and Loss of adesion and detachment (B.b.)	1.3	$a_{8,10} \leq 1.3$		Generic thin cracks of defects at junctions (G.t.)
Broken brick blocks and Loss of adesion and detachment (B.b.)	2.0	$a_{8,11} \leq 2.0$		Decay phenomena (D.p.)
Broken brick blocks and Loss of adesion and detachment (B.b.)	3.0	$a_{8,12} \leq 4.0$		Wood or steel pathology (not heavy) (W.s.)
Component deformation (C.d.)	1.1	$a_{9,10} \leq 1.2$		Generic thin cracks of defects at junctions (G.t.)
Component deformation (C.d.)	1.7	$a_{9,11} \leq 1.8$		Decay phenomena (D.p.)
Component deformation (C.d.)	3.5	$a_{9,12} \leq 3.5$		Wood or steel pathology (not heavy) (W.s.)
Generic thin cracks of defects at junctions (G.t.)	1.5	$a_{10,11} \leq 1.5$		Decay phenomena (D.p.)
Generic thin cracks of defects at junctions (G.t.)	3.0	$a_{10,12} \leq 3.0$		Wood or steel pathology (not heavy) (W.s.)
Decay phenomena (D.p.)	2.0	$a_{11,12} \leq 2.0$		Wood or steel pathology (not heavy) (W.s.)

Fig. 20. - Judgement ranges assigned for the damaged severity alternatives

Damage Severity	(H.f.)	(C.W.)	(E.d.)	(H.e.)	(M.s.)	(P.s.)	(M.c.)	(B.b.)	(C.d.)	(G.t.)	(D.p.)	W.s.	$w_{3,j}$	CR
Heavy foundation problem (H.f.)	1.0	1.0	1.1	1.1	1.9	2.0	2.2	2.5	2.8	3.3	5.1	9.0	10.0	0.0001
Cracks active, cracs wide or Walls leaning out of vertical (C.W.)	1.0	1.0	1.1	1.1	1.9	1.9	2.1	2.4	2.8	3.2	4.7	9.0	9.5	
Excessive deflection, deformations or displacements (E.d.)	0.9	0.9	1.0	1.0	1.8	1.8	2.0	2.4	2.5	3.0	4.5	8.7	9.0	
Heavy expulsion of concrete cover and rebars oxidation (H.e.)	0.9	0.9	1.0	1.0	1.7	1.8	2.0	2.3	2.5	2.9	4.4	8.6	8.8	
Medium settlement or differential settlement (M.s.)	0.5	0.5	0.6	0.6	1.0	1.0	1.1	1.3	1.4	1.7	2.6	5.0	5.1	
Pathology cause of section reduction (P.s.)	0.5	0.5	0.5	0.6	1.0	1.0	1.1	1.3	1.4	1.7	2.4	4.8	4.9	
Medium cracs (M.c.)	0.5	0.5	0.5	0.5	0.9	0.9	1.0	1.1	1.3	1.5	2.3	4.4	4.4	
Brocken brick blocks and Loss of adesion and detachment (B.b.)	0.4	0.4	0.4	0.4	0.8	0.8	0.9	1.0	1.1	1.3	2.0	3.8	3.9	
Component deformation (C.d.)	0.4	0.4	0.4	0.4	0.7	0.7	0.8	0.9	1.0	1.2	1.8	3.5	3.5	
Generic thin cracks of defects at junctions (G.t.)	0.3	0.3	0.3	0.3	0.6	0.6	0.7	0.8	0.9	1.0	1.5	3.0	3.0	
Decay pheomena (D.p.)	0.2	0.2	0.2	0.2	0.4	0.4	0.4	0.5	0.6	0.7	1.0	2.0	2.0	
Wood or steel patology (not heavy) (W.s.)	0.1	0.1	0.1	0.1	0.2	0.2	0.2	0.3	0.3	0.3	0.5	1.0	1.0	

Fig. 21. - Optimized *Judgment Matrix*, Weights, and CR Obtained by O-AHP in *damaged component* Criterion

Damage Extension	100%	90%	80%	70%	60%	50%	40%	30%	20%	10%	$w_{2,j}$	CR
100%	1.0	1.1	1.3	1.4	1.7	2.0	2.5	3.3	5.0	10.0	10.0	0.00001
90%	0.9	1.0	1.1	1.3	1.5	1.8	2.3	3.0	4.5	9.0	9.0	
80%	0.8	0.9	1.0	1.1	1.3	1.6	2.0	2.7	4.0	8.0	8.0	
70%	0.7	0.8	0.9	1.0	1.2	1.4	1.8	2.3	3.5	7.0	7.0	
60%	0.6	0.7	0.8	0.9	1.0	1.2	1.5	2.0	3.0	6.0	6.0	
50%	0.5	0.6	0.6	0.7	0.8	1.0	1.3	1.7	2.5	5.0	5.0	
40%	0.4	0.4	0.5	0.6	0.7	0.8	1.0	1.3	2.0	4.0	4.0	
30%	0.3	0.3	0.4	0.4	0.5	0.6	0.8	1.0	1.5	3.0	3.0	
20%	0.2	0.2	0.3	0.3	0.3	0.4	0.5	0.7	1.0	2.0	2.0	
10%	0.1	0.1	0.1	0.1	0.2	0.2	0.3	0.3	0.5	1.0	1.0	

Fig. 22. - *Judgment Matrix*, Weights, and CR Obtained by AHP in *Damaged extension* Criterion

Position	100%	90%	80%	$w_{4,j}$	CR
First or second floor	1.0	1.8	8.0	10.0	0.01
Third or fourth floor	0.6	1.0	6.0	6.2	
Other	0.1	0.2	1.0	1.1	

Fig. 23. - *Judgment Matrix*, Weights, and CR Obtained by AHP in *Position* Criterion

Criteria	(D.c.)	(D.e.)	(D.s.)	(P.)	v_i	CR
Damaged component (D.c.)	1.0	0.2	0.2	3.0	0.10	0.01
Damage extention (D.e.)	4.5	1.0	1.0	9.0	0.43	
Damage severity (D.s.)	5.0	1.0	1.0	9.0	0.44	
Position (P.)	0.3	0.1	0.1	1.0	0.03	

Fig. 24. - *Judgment Matrix*, Weights, and CR Obtained by AHP in *Criteria*

Finally, Table 6 shows all the criteria and alternatives *weights* obtained by applying the O-AHP methodology to the specific case of R.C. buildings degradation analysis.

Table. 6. Obtained weights by using O-AHP to perform a R.C. buildings degradation analysis

Weights of criteria and alternatives																									
v_1	$w_{1,1}$	$w_{1,2}$	$w_{1,3}$	$w_{1,4}$	$w_{1,5}$	$w_{1,6}$	$w_{1,7}$	$w_{1,8}$	$w_{1,9}$	$w_{1,10}$	$w_{1,11}$	$w_{1,12}$	$w_{1,13}$	$w_{1,14}$	$w_{1,15}$	$w_{1,16}$	$w_{1,17}$	$w_{1,18}$	$w_{1,19}$	$w_{1,20}$	$w_{1,21}$	$w_{1,22}$			
0.1	10	10	9.1	7.9	6.1	6.1	6.1	6.1	6.1	6.1	5.5	2.4	2.2	2.2	1.7	1.7	1.7	1	1	1	1	1			
v_2	$w_{2,1}$	$w_{2,2}$	$w_{2,3}$	$w_{2,4}$	$w_{2,5}$	$w_{2,6}$	$w_{2,7}$	$w_{2,8}$	$w_{2,9}$	$w_{2,10}$															
0.43	10	9	8	7	6	5	4	3	2	1															
v_3	$w_{3,1}$	$w_{3,2}$	$w_{3,3}$	$w_{3,4}$	$w_{3,5}$	$w_{3,6}$	$w_{3,7}$	$w_{3,8}$	$w_{3,9}$	$w_{3,10}$	$w_{3,11}$	$w_{3,12}$	$w_{3,13}$	$w_{3,14}$	$w_{3,15}$	$w_{3,16}$	$w_{3,17}$	$w_{3,18}$	$w_{3,19}$	$w_{3,20}$	$w_{3,21}$	$w_{3,22}$	$w_{3,23}$	$w_{3,24}$	$w_{3,25}$
0.44	3	3.9	8.8	3	4.4	9.5	3	3.9	3.9	3.5	9	9.5	5.1	5.1	10	2	3	3.9	1	4.9	4.9	1	1	4.9	4.9
v_4	$w_{4,1}$	$w_{4,2}$	$w_{4,3}$	$w_{4,4}$	$w_{4,5}$	$w_{4,6}$	$w_{4,7}$	$w_{4,8}$	$w_{4,9}$	$w_{4,10}$															
0.03	10	6.2	1.1																						

4.2 Procedure for calculating the Condition Ratings of the DSS

Once the weights are determined, the KPIs can be used to analyze the building degradation. Fig. 25 schematize the phases of the evaluation in a flow chart.

First the structure is decomposed in class of components, in accordance with the *Matrix of Damage* and the set of alternatives $B_1 = \{b_{1j} \mid j = 1, \dots, \alpha_1\}$, associated to the criterion $i \in C$. criterion C with $\{i = 1\}$.

Secondly, a report is generated on the basis of the visual analysis for each building's damage: every report is composed of a photographic survey and additional structured information, organized in the set of alternatives.

Subsequently, for each reported damage, the 4 tabulated weights of Table 6 are assigned to each alternative. It is worth noting that each weight is associated with only one criterion or alternative. Consequently, the weights can be automatically assigned once the set of alternatives is known.

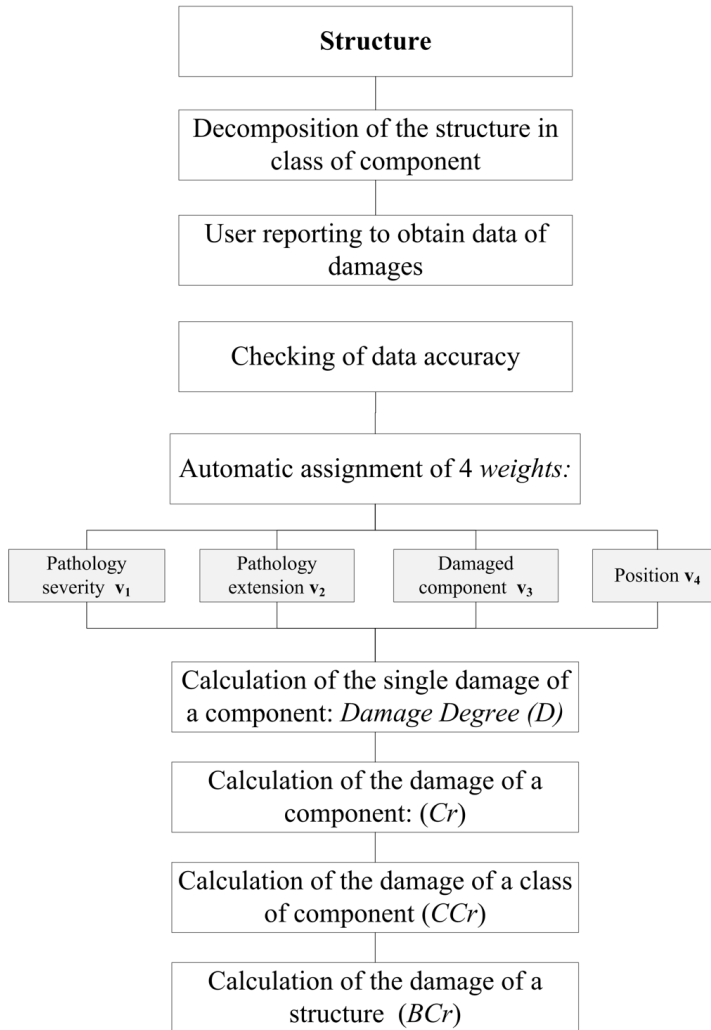


Fig. 25. - Flow chart of the proposed methodology for R.C. building's damages

Once weights are assigned, KPIs (i.e. Cr , CCr and BCr) can be evaluated by using eq (2),(3),(5) respectively. In addition, the necessary coefficient γ_k is calculated for the specific case of R.C. buildings by considered the approximate number components per square meter. To provide an example, in the case of R.C. school building, according to regulatory provisions and construction techniques, 4 columns are approximately present each 36 square meters ($\gamma_2 = 0.03$ column each square meter). The values of γ_k computed in the case of R.C. school buildings are shown in Table 7.

Table 7. Identification of γ_k values in the case of R.C. school building

γ_1	γ_2	γ_3	γ_4	γ_5	γ_6	γ_7	γ_8	γ_9	γ_{10}	γ_{11}	γ_{12}	γ_{13}	γ_{14}	γ_{15}
0.01	0.03	0.02	0.03	0.02	0.02	0.02	0.02	0.02	0.01	0.03	0.01	0.03	0.01	0.03

In addition, a set of limit values are implemented in the procedure in order to provide an immediate alert when one of the KPIs exceeds a predetermined threshold (i.e., when a level of attention is suggested for the safety of the building). When one or more KPIs exceed the corresponding limit value, an alert notification is sent to the QDP.

Fig. 26 shows the limit values assumed for the KPIs, and a corresponding qualitative expression. Levels of colour are associated with each qualitative expression to denote the severity level present in the *Matrix of Damage* or in the diagnostic sheets.

Cr	<i>Local slight damage</i>	<i>Local medium damage</i>	<i>Local serious damage</i>
	$Cr < 4$	$4 \leq Cr < 6$	$6 \leq Cr \leq 10$
CCr	<i>Few damages and limited to a class of components</i>	<i>Medium damages on a class of components</i>	<i>Serious and extended damage</i>
	$CCr < 2$	$2 \leq CCr < 6$	$6 \leq CCr \leq 10$
BCr	<i>Building in good condition</i>	<i>Medium widespread damages</i>	<i>Serious and extended danger compromising whole building</i>
	$BCr < 3$	$3 \leq BCr < 5$	$5 \leq BCr \leq 10$

Fig. 26. - Limit values and the corresponding qualitative expression and associate color

4.3 Application example of the Condition Ratings

The described methodology has been applied to a set of R.C. school buildings located in the municipality of Bari. Two cases, school building “Cirielli” and school building “Lopopolo”, are discussed. They are particularly interesting, since they exhibit similar pathologies but provide quite different diagnostic results.

The school building “Cirielli” is located in the city of Bari, in the district of San Paolo. It was completed in 1963 and is composed by two RC building blocks with a deck area of 1226 square meters. The “Cirielli” is a two-storey building (ground and first floor) with max height of 11.24 meters (calculated from the top of the stairwell). The ground floor of 1226 square meters consists of two corridors from which all the classrooms

can be accessed. The two corridors are developed on two different altitudes that differ by 0.8 meters and are connected by a small staircase. The first floor is 118 square meters and it is developed in the central part of the L-shaped building plan. This school is equipped with large outdoor areas, which are developed on each side of the building, partly wooded, including an area used for parking.

The school building “Lopopolo” is located in the city of Bari, in the district of San Paolo. It was completed in 1966 and is composed by a single RC building blocks. In the year 2004 an extension of 270 square meters has been made reaching a deck area of 1490 square meters. The “Lopopolo” is a single-storey building with a surface of 1490 square meters and max height of 4.3 meters. The school consists of a rectangular central body and a trapezoidal area that develops with an open plan scheme. The building is equipped with large outdoor areas, which are developed on each side of the building.

In the first phase of data acquisition, the *Building Registry Tabs* have been filled with the information provided by the municipal office and integrated by the existing national database. Fig. 27 shows the *Building Registry Sheets* for the school building “Lopopolo”.

Decision Support System
Building Registry Tabs

BUILDINGS REGISTRY TAB					
General Data					
	Registry Data				
	Country		Italia		
	Region		Puglia		
	City		Bari		
	Address		street Viale Lazio		
	Street number		5		
	GPS		Lat 41.1192170; Long. 16.7933123		
	Occupancy		School		
	Building name		"Lopopolo"		
			Age		
Project		1963			
End of works		1966			
Geometric data and constructive type					
Buildings blocks	n°	1		Staircase typology	-
Seismic Joint			☐ Yes ☒ No	Slab typology	Mixed R.C. and brick
Structural typology			R.C. frame	Geomorphology	Rocky terrain
Curtain wall typology			Tuff or brick	Aquifer location	unknown
Total Area	m ²	1490		Max Height	m 4.3
Floors/above ground	n°	1 / 1		Volume	m ³ 4800
Foundation level Area	m ²	1490		Room number	n° 26
Area floor 0	m ²	1490		External staircase	n° 0
-	m ²	-		Internal staircase	n° 0
Deck area	m ²	1490		Elevator	n° 0
Original Projects Availability					
Preliminary Project				not available	
Definitive Project				not available	
Executive Project				not available	
Interventions or modifications					
Typology		Date (year)	Description	Documentation	
☐ New floor					
☐ Internal modifications					
☐ New openings					
☒ Extensions		2004	Extension of a gym	Not present	
☐ Elevator					
Ordinary maintenance interventions					
☐ Minor interv. on building systems					
☒ Intervention of internal finishes		2004	External doors		
Extraordinary maintenance interventions					
☐ Interventions on Internal walls					
☐ Interventions building systems					
☐ Interventions on building envelope					
☐ Elevator					
Vulnerability assessments					
Typology		Date (year)	Description	Documentation	
☐ Vulnerability assessments					
☐ Vulnerability assessments					
Reference technical codes					
Typology		Date (year)	Description	Documentation	
R.D.L. 29 luglio 1993 n.682		1993	Building technical codes		

Fig. 27. - Registry Tab of school building "Lopopolo", Bari, Italia

For school building "Cirielli", the users has reported 56 damages in 45 different component of the structure. In Fig. 28 and Fig. 29, one questionnaire of a certified user and the corresponding report results stored in the *Diagnostic Tabs* are shown respectively.

In particular, Fig. 28 describes the set of questions generated in the case of a report concerning the heavy concrete spalling in a beam. In such a case, 9 questions are proposed to the User. In the figure among the possible answers, the user's response is indicated in grey.

APP QUESTIONNAIRE: CERTIFIED USER								
1 WHERE DO YOU MADE THE PHOTO?	2 INSERT FLOOR PLAN LOCATION	3 IN WHICH ROOM DO YOU PHOTOGRAPH THE CRITICALITY?	4 WHICH IS THE CRITICALITY HEIGHT ABOVE WALKING SURFACE?	5 WHAT IS EXACTLY UPSTAIRS?	6 WHICH ELEMENT DID YOU PHOTOGRAPH?	7 WHICH IS THE DAMAGED ELEMENT MATERIAL?	8 WHICH CRITICALITY DID YOU PHOTOGRAPH?	9 WHICH IS THE DAMAGE EXTENTION COMPARED WITH THE ELEMENT DIMENSION?
Outdoor Indoor	Insert...	Office Room Entrance or hallway Storeroom	Less than 1,5m Between 1.5m and 2m Between 2m and 3m Between 3m and 4m	Other floor Building top Attic Insert other...	Foundation Column Beam Floor	Concrete Wood Steel Glass	Rebars oxidation cracking Spalling Heavy concrete spalling Component deformation	... 60% 50% 40%

Fig. 28. - Questionnaire of a certified user (report of a heavy concrete spalling)

The *Diagnostic Tab* (Fig. 29) shows the results of the questionnaire and the classification of the related information, such as criteria, alternatives and their associated weights, according to the proposed methodology.

Such sheets allow to display the photographic inspections and to check, and eventually correct, the information used to the automatic evaluation of the *Criticality Condition Rating*. Fig. 29 depicts the report obtained for inspection $h=26$ and the corresponding $Cr^{26} = 7.2$ obtained by (6). Such value exceeds the limit of *local serious damage* according to Fig 26. Hence, the DSS provides a warning signal by a red background in the box of Cr .

All reported pathologies are stored and displayed in the right part of the *Matrix of Damage* (Fig. 30), that shows the number of damages for each type of criticality (matrix columns) and for each component (matrix rows). The colour of the cell indicates the maximum Criticality Condition Rating surveyed corresponding to the selected element and damage, according to the rules of Fig. 26. The left part of the matrix points out the maximum value of Cr detected on the building (*Max Criticality Condition Rating*), the *Building Condition Rating* and the *Component Condition Ratings (CCr)*.

the *Component Condition Ratings* don't exceed 2, i.e., the pathologies affecting the component classes do not compromise the overall component effectiveness; iii) the *Building Condition Rating* does not exceed the limit of 3, i.e., in the building there is a widespread extension of damages, but few of them are serious.

The second application of school building "Lopopolo", for which 73 damages in 45 different component of the structure have been obtained. Fig. 31 shows the corresponding *Matrix of Damage*.

SC2	BUILDINGS		School Lopopolo		MATRIX OF DAMAGE			Code	Max. Type	Max. Value	Building Damage	Criticality																
	ADDRESS		Registry data																									
	Viale Liano 8																											
Deviation Support System Survey output					Construction date: 1966			Cracks caused by rebar corrosion	R.C. Corrosion			Cracking pattern			Defect in giuntion and detachment			Component deformation			Se			De				
					Reginy data				Ox1	Ox2	Ox3	Cr1	Cr2	Cr3	Gi1	Gi2	Gi3	Df1	Df2	Df3	Se1	Se2	Se3	De1	De2	De3		
					Total area: 1490 m²																							
					N° of Floors: 1																							
					Construction typology: R.C.																							
					N° of buildings blocks: 1																							
					Average Knowledge degree				Spalling			Heavy concrete spalling																
					Certified user				Thin cracks			Medium cracks			Wide or active cracks			Defects at junction			Detachment of elements			Brick blocks falling down				
					Max Criticality Condition Rating:				Medium cracks			Wide or active cracks			Defects at junction			Detachment of elements			Brick blocks falling down			Component deformation				
					9.8				Medium cracks			Wide or active cracks			Defects at junction			Detachment of elements			Brick blocks falling down			Component deformation				
					Building Condition Rating:				Medium cracks			Wide or active cracks			Defects at junction			Detachment of elements			Brick blocks falling down			Component deformation				
					2.14				Medium cracks			Wide or active cracks			Defects at junction			Detachment of elements			Brick blocks falling down			Component deformation				
Tech. Unit		Element		Sub-Element		Component		Code		Code		Code		Code		Code		Code		Code		Code		Code		Code		
Code	Type	Code	Typology	CCC	Code	Code	Component	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code		
S	Structural	S1	Foundation	0.00	S1.1		Foundation																					
				0.00	S1.2		Shear wall																					
		S2	Structural element	0.00	S2.2		Column																					
				0.14	S2.3		Beam																					
				0.00	S2.4		Braced frame																					
L	Load bearing	L1	Slab	0.92	L1.1		Floor slab																					
				0.00	L1.2		Roof																					
				0.00	L1.3		Ground floor																					
		L2	Connection	0.00	L1.4		Balcony or projection																					
				0.00	L2.1		Staircase																					
				0.00	L2.2		Catwalks																					
N	Non load bearing	N1	Facade envelope	0.02	N1.1		Curtain wall																					
				0.00	N1.2		Windows fixture																					
				0.00	N1.3		Skylight window																					
		N2	External wall	0.26	N2.1		External R.C. wall																					
				0.00	N2.2		External brick wall																					
				0.00	N2.3		Breastwork																					
		N3	Internal finishes	0.00	N3.1		Internal wall																					
				0.00	N3.2		False ceiling																					
				0.00	N3.3		Door																					
		N4	Other	0.07	N4.1		Joint between elements																					
				0.00	N4.1		Elevator																					
				0.00	N4.1		Elevator																					

SC2 Decision Support System APP Report	BUILDINGS		School Lopopolo		Diagnostic Tab			
	ADDRESS		Viale Lazio 5		Photographic survey			
	id component	data-photo	data-insert	data-creation	Knowledge Degree	username	id structure	name
	e=44	24/04/17	24/04/17	24/04/17	Technician	Valentino Mail ####	1	"Lopopolo"
					Criticality			
					Damaged component		Balcony or projection	5.5
					Damage extension		100%	10.0
					Damage severity		Heavy concrete spalling	8.8
					Component position		First of second floor	10
					Cr ¹⁴		Local serious damage	7.2
	Questionnaire					Answers		
	Where do you made the photo?					Out-door		
	Insert floor plan location of the problem					0		
	In which room do you photograph the criticality?					Courtyard		
	Which is the criticality height above walking surface?					Between 3m and 4m		
	What is exatly upstairs?					Building top		
	Which element do you photograph?					Balcony or projection		
	Which is the damage extention compared with the element dimension?					100%		
	Which is the damaged element material?					Concrete		
	Which criticality did you photograph?					Heavy concrete spalling		

Fig. 32. - Diagnostic Tab, heavy concrete spalling of a projection in school building "Lopopolo", Bari, Italia

The DSS comparison of these two buildings suggests a priority of intervention for the Lopopololo school that presents the highest number of pathologies and the highest values of building *Cr* and *Ccr*. Furthermore, the overview of the building reports through the diagnostic sheets points out that the specific actions involved in the intervention priority are the rehabilitation of the concrete cover in the sunshades (Fig. 32) and of the curtain walls' finishing, in order to ensure user safety and building proper operability.

5 CALIBRATION OF KEY PERFORMANCE INDICATORS THROUGH TUUTTI MODEL AND COMPARISON WITH THE METHODOLOGY “GDE-UNB”

In this section the obtained weights to set the KPIs are calibrated through the Tuutti model in order to consider the damage evolution of reinforcements' corrosion. In addition, in order to assess the effectiveness of the evaluated KPIs a comparison with the GDE-UnB is proposed. Such method is particularly interesting and allied with the proposed one, because it evaluates three performance indicators assessing, respectively, the condition of the single components, the class of the components and the whole building.

In particular, two steps are performed in order to make an exhaustive analysis of the effect of the calibration.

First, a comparison between the proposed KPIs and the performance indicators of GDE-UnB is performed through a set of case studies and by analyse the results of a sensitivity analysis to verify the robustness of the formulations.

Secondly, the weights of the proposed KPIs are calibrated with exploiting the Tuutti model (1982). An additional sensitivity analysis is performed in order to evaluate the impact of the calibration on the result and obtain a suitable calibration of the formulas.

5.1 The GDE-UnB Methodology: “Degree of Element Deterioration” (GDE-UNB)

In this section the GDE-UnB method (Castro, 1994) is presented in order to perform a comparison with the proposed DSS approach.

The GDE-UnB methodology, developed on the basis of the studies of Tuutti on the rebar oxidation of R.C., aims to establish a quantification of the degree of deterioration of a R.C. structure. The method is based on KPIs that consider the most frequent manifestations of damages affecting some isolated structural elements or the whole structure. In this section the formulas improved in (Boldo 2002) are discussed. The flow chart of Fig. 3 summarizes the methodological steps of the evaluation.

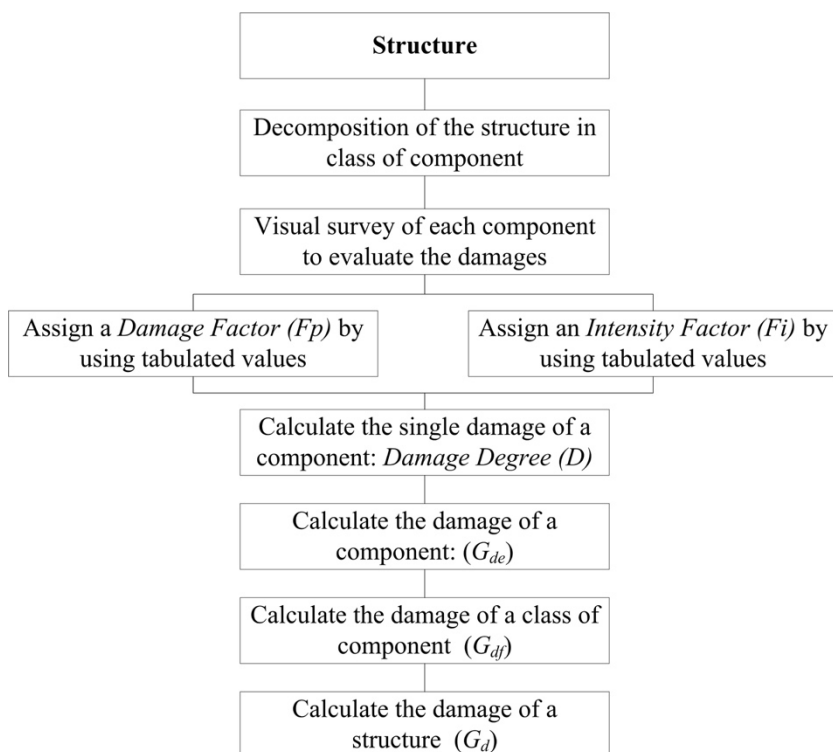


Fig. 33. - Flow chart of the steps of the GDE-UnB methodology to evaluate the building degradation

The first step is the decomposition of the structure into F classes of components (shear wall, column, beam, etc.).

In the second step, a visual survey of each component is performed to evaluate the damages.

Third, for each component two weighting factors are assigned: a *damage factor* (F_p) and an *intensity factor* (F_i). The *damage factor* (F_p) is an integer tabulated weights, variable from 1 to 5 (Castro, 1994) and is assigned in order to quantify the level of importance of a damage on the basis of the visual survey of the damage and the functionality and safety of the component.

Analogously, the *intensity factor* (F_i) is an integer tabulated weights, variable from 1 to 5 assigned by surveyor on the basis of the R.C. pathologies (Fonseca 2010).

The forth step of the method is the evaluation of the single damage by an index named *damages degree*.

Let us consider a generic component e and the Δ detected damages related to e . The method Gde-UnB exploits the Tuutti model (1982) generalized by the Model Code MC-90 CEB-FIP (Comité euro-international du béton 1993) to obtain the damage formulation index, denoted by *damages degree* D_d with $d=1, \dots, \Delta$.

The *damages degree* of a single damage is evaluated as follows:

$$\text{if } Fi \leq 2 \text{ then } D_d = 0,4Fi \cdot Fp \quad \text{for } d = 1, \dots, \Delta \quad (16)$$

$$\text{if } Fi \geq 3 \text{ then } D_d = (12Fi - 28) \cdot Fp, \quad \text{for } d = 1, \dots, \Delta \quad (17)$$

Once obtained the *single damage* D_d , the synthetic KPI (Gd_e) devoted to quantifying the deterioration of a component is defined as a function of the values of D_d as follows (Boldo 2002):

$$Gd_e = D_{max} \left(1 + \frac{\sum_{d=1}^{\Delta} D_d - D_{max}}{\sum_{d=1}^{\Delta} D_d} \right), \quad (18)$$

where D_{max} is the maximum value obtained for D_d , with $d=1, \dots, \Delta$.

The synthetic index Gd_f expresses the deterioration of the generic component class f and is calculated by aggregating the values of Gd_e representing the deterioration of the components e belonging to the f^{-th} class (obtained by eq. (12)). More precisely, the value of Gd_f is computed as follows:

$$Gd_f = Gd_{e, max} \sqrt{1 + \frac{\sum_{e=1}^E Gd_e - Gd_{e, max}}{\sum_i^n Gd_e}}, \quad (19)$$

where $Gd_{e, max}$ is the maximum value obtained for Gd_e . Only the elements with $Gd_e \geq 15$ are involved in the Gd_f calculation.

Finally, the degree of deterioration of the whole structure (G_d) is calculated by the arithmetic weighted average of the k values of Gd_f according to the equation below:

$$G_d = \frac{\sum_{f=1}^F G d_f Fr_f}{Fr_f}, \quad (20)$$

where the values of Fr_f are tabled values of the structural relevance defined for every class of components f and showed in (Boldo 2002).

5.2 Comparison of general aspects

The differences between the two methods are now analyzed in order to identify the necessary operations and set up a comparison of the methodologies through case studies applications. The two methods have the same methodological structure in the calculation of the KPIs, as it can be seen from Fig. 25 and Fig. 33. The main difference between the two “*single damage*” formulations consists in the Tuutti model used by GDE-UnB to derive the formulation.

Table 8. Comparison between GDE-UnB and the proposed DSS approach

	DSS	GDE-UnB
General considerations	1) Data acquisition performed through User reporting 2) validation of acquired data by a technician (engineer) 3) calculation of KPIs on the basis of tabulated weights obtained by O-AHP	Methodology directly applied by a surveyor to evaluate KPIs on the basis of tabulated weights defined by experts
Factors or criteria	Final goal: structural degradation - non-structural pathologies regarding plaster or veneer are considered - R.C. and wood pathologies are considered	Final goal: structural degradation - Non-structural pathologies regarding plaster or veneer are not considered - Only R.C. pathologies are considered
Single Damage (SD_d and D_d)	Weighted average formula $SD_d = 1, \dots, 10$	Factorial formula Calibrated with Tuutti model $D_d = 1, \dots, 100$
Single component (Cr_e and Gd_e)	Cr_e Inspired by Gd_e and tuned	Gd_e
Class of components (CCr_f and Gd_f)	Normalized with respect to the total number of components actually present in the building	Not Normalized great importance is given to the most damaged component
Structure index (BCr and G_d)	Normalized with respect to the total number of components actually present in the building	Not Normalized

In addition, the single damage and the *Single component* evaluation are calculated with different normalization, as the numerical result varies from 0 and 100 in the GDE-UnB and from 0 and 10 in the DSS KPIs. This difference can be easily overcome with a linear transformation to perform a comparison of the methods. Table 8 summarizes the differences between the two methods.

5.3 Comparison through case studies

The GDE-UnB and the DSS methodologies are applied to a set of R.C. structures built between 1960 and 1980 and located in the municipalities of Bari (Italy), Porto (Portugal) and Fortaleza (Brazil). The considered four case studies are shown in Fig. 34: “Cirielli School Building (Bari)”, “Lopopolo School Building (Bari)”, “FEP Faculty of Economy (Porto)” and a “Brazilian Elevated storage tank (Fortaleza)”. These structures are particularly interesting for the comparison of the methods, since they exhibit different pathologies and quite different dimensions and structure typologies.



School building “Cirielli”



School building “Lopopolo”



“Faculdade de Economia” in
University of Porto



“Brazilian elevated
storage tank ”

Fig. 34. - Main facade of the four case studies.

For all the case studies, the GDE-UnB and DSS methodologies are applied to evaluate every single damaged component and the resulting values are normalized to 1.

In order to accomplish the comparison, the following index, named *Difference index*, is defined to assess the overall differences between the two method results and is evaluated for each building:

$$\text{Difference Index} = \frac{\sum_{i=1}^E |Cr_e - Gd_e|}{E} \quad (20)$$

Fig. 34 shows an extract of the *Diagnostic Tabs* surveyed on a single component of the school “Lopopolo”, in addition the component KPI is evaluated with the GDE-UnB and DSS methodologies. The identified pathologies are the spalling and the presence of a wet area in a concrete projection. Fig. 35 shows a small wet area surveyed in FEP Faculty of Economy. Also this figure shows the evaluation of the damage of the *single component* with the two methods.

SC2	BUILDINGS ADDRESS	School Lopopolo Viale Lazio 5	Diagnostic Tab		
			Photographic survey		
Decision Support System APP Report			Criterion	Alternative	w _{ij}
			Damaged component	Balcony or projection	5.5
			Damage extension	40%	4.0
			Damage severity	Spalling	3.9
			Component position	First of second floor	10
			D ₁		4.3
			Criterion	Alternative	w _{ij}
			Damaged component	Balcony or projection	5.5
			Damage extension	40%	4.0
			Damage severity	Decay phenomena (wet area, ...)	2
			Component position	First of second floor	10
			D ₂		3.5
			Criticality Condition Rating (Cr _e) ^{normalized to 1}		
			0.52		

SC2	BUILDINGS ADDRESS	School Lopopolo Viale Lazio 5	Diagnostic Tab		
			Photographic survey		
Decision Support System APP Report			Factor	Description	Tabuled weight
			Damage Factor (F _p)	Balcony or projection	5
			Intensity Factor (F _i)	Oxidation cracks or spalling	3.0
			D ₁		40.0
			Factor	Description	w _{ij}
			Damage Factor (F _p)	Balcony or projection	3
			Intensity Factor (F _i)	Decay phenomena (wet area, ...)	3.0
			D ₂		24.0
			Gd _e ^{normalized to 1}		
			0.55		

Fig. 35. - Case Study of School “Lopopolo”: single component KPI calculation regarding the expulsion of concrete cover of a balcony or projection for both methodologies.

FE	BUILDINGS	Facultade de Economia	Diagnostic Tab		
	ADDRESS	R. Dr. Roberto Frias 464	Photographic survey		
Decision Support System APP Report		Criterion		Alternative	w_g
		Damaged component		Floor Slab	5.5
		Damage extension		40%	4.0
		Damage severity		Decay phenomena (wet area, ...)	3.9
		Component position		First of second floor	10
		D_I			3.5
		Criticality Condition Rating (Cr_c)		<i>normalized to 1</i>	0.35

FE	BUILDINGS	Facultade de Economia	Diagnostic Tab		
	ADDRESS	R. Dr. Roberto Frias 464	Photographic survey		
Decision Support APP Report		Factor		Description	Tabuled weight
		Damage Factor (F_p)		Wet framework	3
		Intensity Factor (F_i)		Medium wet stain	2.0
		D_I			4.8
		Gd_c		<i>normalized to 1</i>	0.04

Fig. 36. - Case Study of “FEP”: single component KPI calculation regarding the wet framework of a floor slab for both methodologies.

Fig. 37 shows the values of the first twenty reports of the school “Cirielli”. It is worth noting that the difference between the two formulations increases when the damage is not heavy. This aspect is analysed in detail in paragraph 5.5, where the Tuutti model calibration is implemented and analysed. In addition, Fig. 38 shows the *Difference Index* evaluated on all the case studies by using Eq. (20).

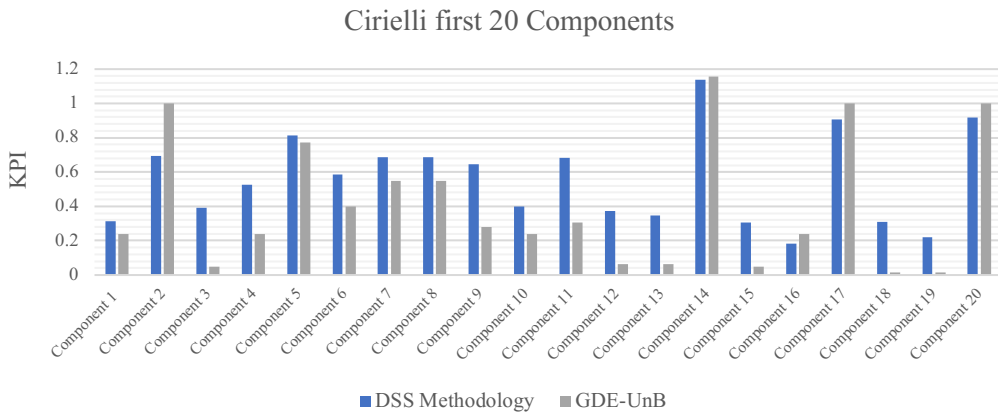


Fig. 37. - Case Study of School “Cirielli”: evaluation of the single component KPI for the first 20 damaged component.

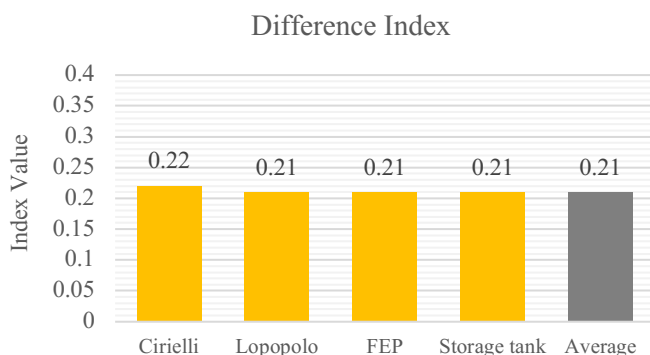


Fig 38. - *Difference Index*: individual values for the 4 case studies and average

The *Difference Index* found for the 4 case studies is about equal to 0.21, confirming that the two methods behave in the same way also changing the typology of the case study.

5.4 Sensitivity analysis

An important comparison of the two methods has been performed through a sensitivity analysis. A *Numerical Incremental Analysis (NIA)* is carried out by incrementally changing the numerical values of specific *parameters* and graphically or numerically showing the corresponding trend of changes in the results (Leonelli, 2012).

In the proposed methodologies, some parameters can be affected by the surveyor subjectivity. Hence, the *parameters* for which an objective evaluation is not assured during the application have been selected for the *NIA*.

In the GDE-UnB method, the *intensity factor* (F_i) is subject to possible different interpretations, then it has been chosen for the incremental changing.

In the DSS method, the incremental changing is applied to the *damage extension* and to the *damage severity* criteria, since they are not perfectly objectively evaluable.

The perturbation is given by modifying the *intensity factor* (F_i), the *damage extension* and the *damage severity* criteria by replacing them with the immediately higher or lower tabulated weights.

In order to perform the comparison on all the reports of the case studies, an additional

index (*Sensitivity Index (SI)*) able to assess the overall differences between the two methods has been defined:

$$SI(DSS) = \frac{\sum_{e=1}^E |(Cr_e - Cr'_e) / Cr_e|}{E}, \quad (21)$$

$$SI(GDE-UnB) = \frac{\sum_{e=1}^E |(Gd_e - Gd'_e) / Gd_e|}{E} \quad (22)$$

Where, for the considered building, Cr_e (Gd_e) is the non-perturbed value and Cr'_e (Gd'_e) is the value after perturbation by using DSS KPIs (respectively, GDE-UnB) methodology.

Fig. 39 and Fig. 40 show the perturbed value for the chosen parameters and the perturbed result for the case of the report previously shown. These images illustrate a recurrent example in which the GDE methodology results considerably less robust than DSS KPIs, as it can be noted from the perturbed valued of Cr (that varies between 0.43 and 0.83) and Gd_e (that varies between 0.11 and 1.38).

BUILDINGS ADDRESS	School Lopopolo Viale Lazio 5	Diagnostic Tab Photographic survey		
		Criterion	Alternative	w_g
		Damaged component	Balcony or projection	5.5
		Damage extension	40%	4.0
		Damage severity	Spalling	3.9
		Component position	First of second floor	10
		D_1		
				4.3
		Criterion	Alternative	w_g
		Damaged component	Balcony or projection	5.5
		Damage extension	40%	4.0
		Damage severity	Decay phenomena (wet area, ...)	2
		Component position	First of second floor	10
		D_2		
				3.5
		Criticality Condition Rating (Cr_e) normalized to 1		
				0.52

BUILDINGS ADDRESS	School Lopopolo Viale Lazio 5	Diagnostic Tab Photographic survey		
		Criterion	Alternative	w_g
		Damaged component	Balcony or projection	5.5
		Damage extension	50%	5.0
		Damage severity	Heavy concrete spalling	3.9
		Component position	First of second floor	10
		D_1		
				6.7
		Criterion	Alternative	w_g
		Damaged component	Balcony or projection	5.5
		Damage extension	50%	5.0
		Damage severity	Cracking of plaster or sensor	3.9
		Component position	First of second floor	10
		D_2		
				4.5
		Criticality Condition Rating (Cr_e) normalized to 1		
				0.83

BUILDINGS ADDRESS	School Lopopolo Viale Lazio 5	Diagnostic Tab Photographic survey		
		Criterion	Alternative	w_g
		Damaged component	Balcony or projection	5.5
		Damage extension	40%	3.0
		Damage severity	Cracks caused by rebar cold	3.0
		Component position	First of second floor	10
		D_1		
				2.3
		Criterion	Alternative	w_g
		Damaged component	Balcony or projection	5.5
		Damage extension	40%	3.0
		Damage severity	Decay phenomena (wet area, ...)	2.0
		Component position	First of second floor	10
		D_2		
				1.9
		Criticality Condition Rating (Cr_e) normalized to 1		
				0.43

Fig. 39. - Sensitivity analysis of DSS formulation: calculation of the single component KPI for the school building “Lopopolo”

KPI	BUILDINGS ADDRESS	School Lopopolo Viale Lario 5	Diagnostic Tab		
			Photographic survey		Tabulated weight
Decision Support System APP Report			Factor		
			Damage Factor (Fp)	Balcony or projection	5
			Intensity Factor (Fi)	Oxidation cracks or spalling	3.0
			D ₁		40.0
			Factor		w _g
			Damage Factor (Fp)	Balcony or projection	3
			Intensity Factor (Fi)	Decay phenomena (wet area, ...)	3.0
			D ₂		24.0
			Gd ₁ normalized to 1		0.55

KPI	BUILDINGS ADDRESS	School Lopopolo Viale Lario 5	Diagnostic Tab		
			Photographic survey		Tabulated weight
Decision Support System APP Report			Factor		
			Damage Factor (Fp)	Balcony or projection	5
			Intensity Factor (Fi)	Heavy Rebar oxidation	4.0
			D ₁		100.0
			Factor		w _g
			Damage Factor (Fp)	Balcony or projection	3
			Intensity Factor (Fi)	Generalized wet framework	4.0
			D ₂		60.0
			Gd ₂ normalized to 1		1.00

KPI	BUILDINGS ADDRESS	School Lopopolo Viale Lario 5	Diagnostic Tab		
			Photographic survey		Tabulated weight
Decision Support System APP Report			Factor		
			Damage Factor (Fp)	Balcony or projection	5
			Intensity Factor (Fi)	Oxidation cracks or spalling	2.0
			D ₁		8.0
			Factor		w _g
			Damage Factor (Fp)	Balcony or projection	3
			Intensity Factor (Fi)	Decay phenomena (wet area, ...)	2.0
			D ₂		4.8
			Gd ₃ normalized to 1		0.11

Fig. 40. - Sensitivity analysis of GDE-UnB formulation: calculation of the single component KPI for the school building “Lopopolo”

In order to display all the analysis and appraise the trend of changes, the range of variation of the results is represented in a graph for each case study. The sensitivity analysis graph of the DSS and GDE, respectively, for the first 20 reports of the school building “Cirielli” is reported (Fig. 41 and Fig. 42). In these graphs, the upper bound and the lower bound of the variation of the sensitivity are indicated.

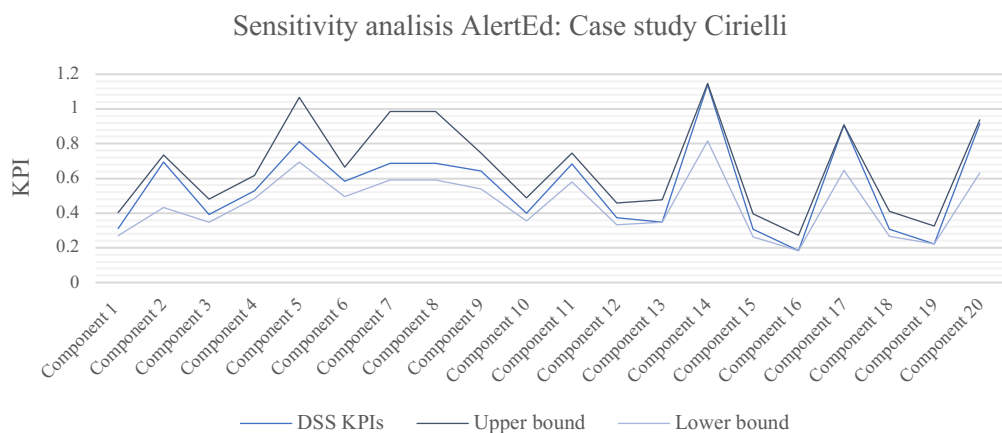


Fig. 41. - Sensitivity analysis graph of DSS KPIs: case study of Cirielli

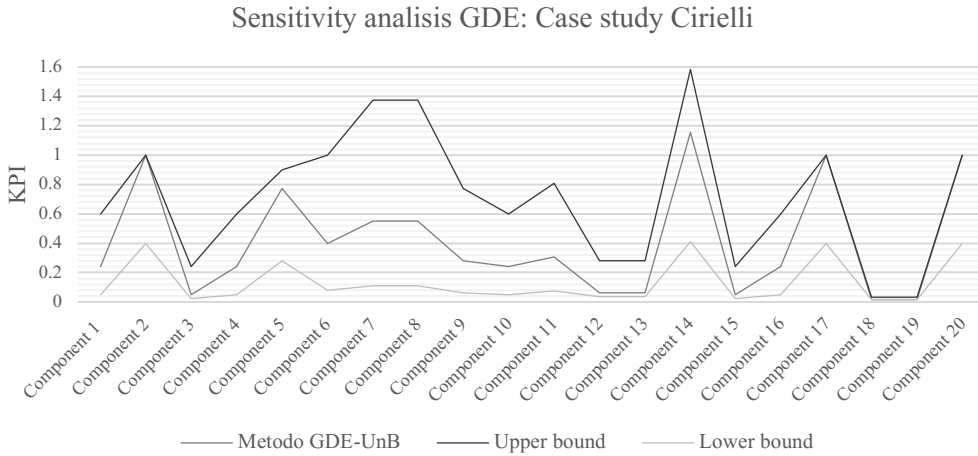


Fig. 42. - Sensitivity analysis graph of GDE KPIs: case study of Cirielli

The plots of the sensitivity analysis confirm a greater change of the GDE results as can be appreciated from the greater difference between upper bound and the lower bound in the graph of GDE UnB (Fig. 42) in comparison with the graph of DSS KPIs (Fig. 41). In order to have a numerical indicator of the differences between the two methods, Fig. 43 reports the *Sensitivity Indexes* of all the case studies obtained by Eq. (21) and (22).

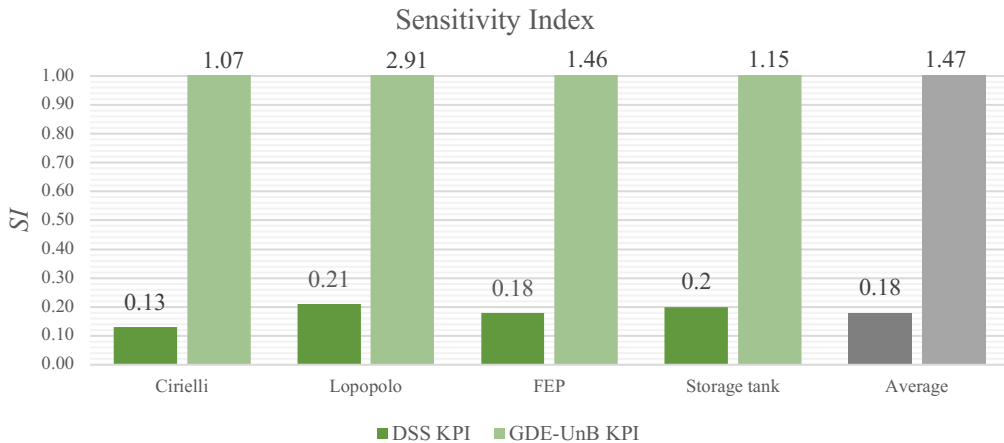


Fig. 43. - *Sensitivity Index* obtained for every case study and for the two methodologies

In the DSS, the *Sensitivity Index* is equal to 0.18 on average with respect to all the case studies (in general, the value of the perturbed report on average differs of 18% from the non-perturbed one). On the contrary, in the GDE, the incremental or decremental value exceeds on average the 100% of the initial values. The low robustness of the GDE-UnB is partially due to the factorial formula that involves only two factors. Therefore each factor has a great impact on the final value.

5.5 Calibration of the DSS KPIs through Tuutti model

In this paragraph, the Tuutti calibration is used to improve the DSS methodology. In particular, the criteria and alternative weights of DSS for which the Tuutti model is theoretically applicable are considered and calibrated. In addition, intermediate calibration levels are considered through a formulation which provides a step by step increment. This operation is essential to understand how the Tuutti model influences the comparison of methods and the results of sensitivity analysis.

The Tuutti model is used to perform the calibration by exploiting the formulation developed by Marques et al. (2016). This formulation replaces the linear model used in the original methodology (Fonseca, 2007) by a cubic parabola obtained by a linear regression adjusted to the points of the original model. Such formulation has the advantage of combining into a single expression the two necessities formulas to define the bilinear one.

In agreement with the theory of Tuutti, the criteria of the DSS methodology that can be calibrated are the *Damage extension* and the *Damage severity* criterion. In addition, intermediate calibration levels are considered through a novel formulation based on the Marques et al. (2016), which provides a weighted average of the uncalibrated and full calibrated model.

The calibrated weights $w'_{ij}{}^k$ are evaluated by using the following formula:

$$w'_{ij}{}^k = k(0,0741 + 1,3905 w_{ij} - 1,599 w_{ij}^2 + 0,6274 w_{ij}^3) + [(1 - k)w_{ij}]$$

for $i = [1,2]$

(23)

where $0 < k < 1$ is a coefficient representing the rate of the Tuutti calibration in the new weights. Fig. 44 shows the calibration of *Damage extension* criterion by displaying five values of k : the non-calibrated values ($k=0$), the “full” Tuutti calibration ($k=1$) and intermediate values. On the abscissas axis the rate of the *Damage extension* is reported and on the ordinates axis the weight normalized from 0 to 10 is reported.

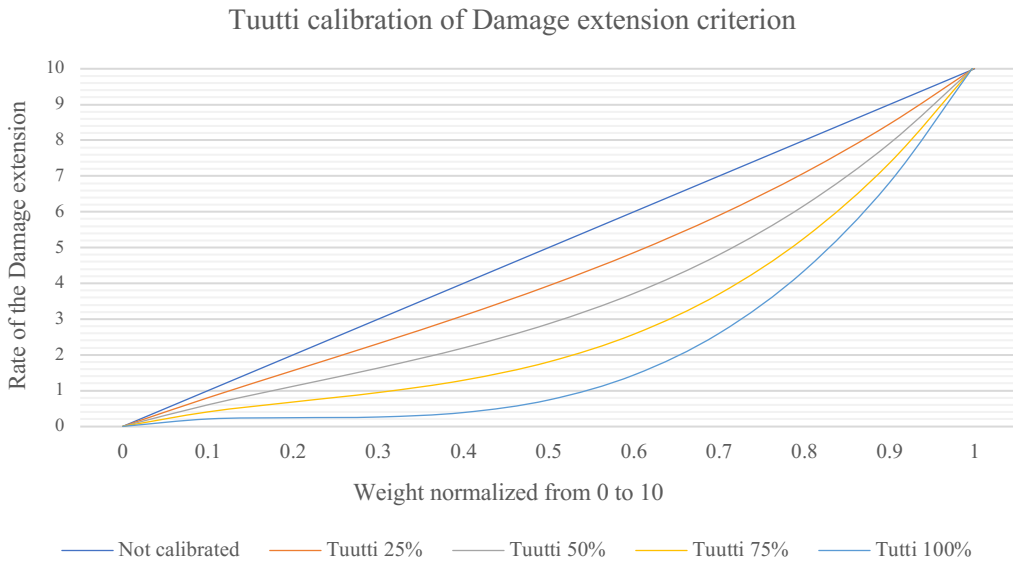


Fig. 44. - Tuutti calibration graph of the Damage extension criterion

5.6 Identification of the best calibration point for DSS KPIs

In order to evaluate the impacts of the calibration through Tuutti model on the DSS KPIs, a comparison and a sensitivity analysis (as already described in par 5.4) have been performed for each calibration obtained by changing the value of k in the formulation (23).

By changing k , a set of values regarding *Difference Index* and *Sensitivity Index* is obtained from the different calibration of DSS KPIs and applied to the case studies. Such data are elaborated by using a polynomial interpolation of degree 3 in MATLAB environment to represent in an approximate way the function of the *Difference Index* varying k and the function of the *Sensitivity Index* varying k . The obtained Polynomial curves are given by Eqs (24), (25) and plotted in Fig. 15:

$$\text{Difference index} = 0.0098x^3 + 0.0142x^2 - 0.0513x + 0.1425 \quad (24)$$

$$\text{Sensitivity index} = 0.02x^3 + 0.0242x^2 - 0.0509x + 0.2455 \quad (25)$$

where

$$x = \frac{k-50}{39.5} \quad (26)$$

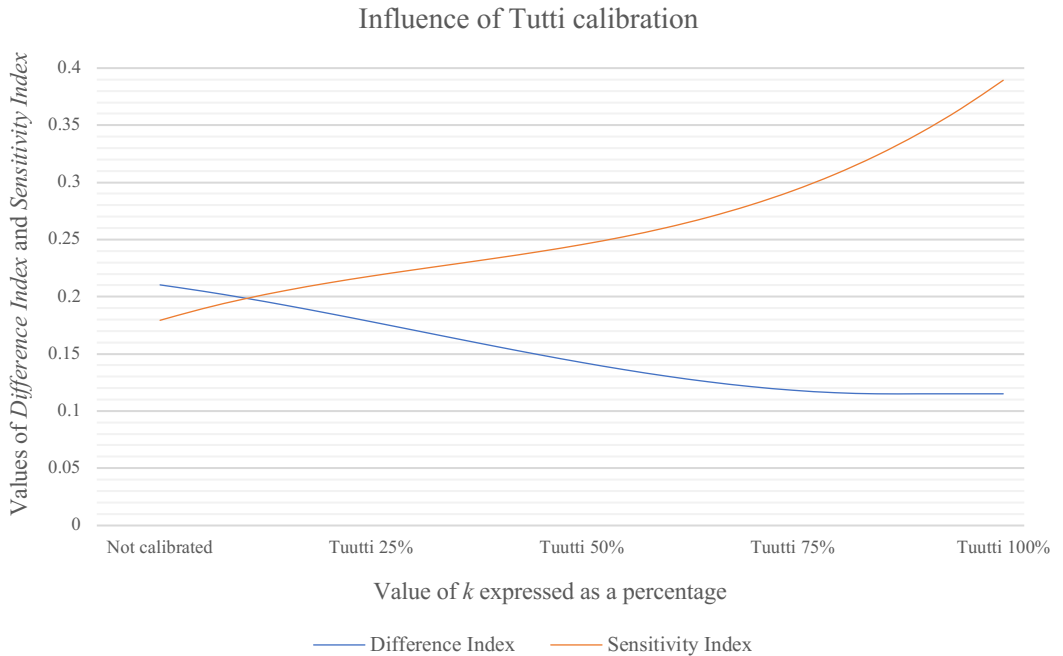


Fig. 45. - Curves of the *Difference Index* and the *Sensitivity Index* obtained changing k

The performed analyses emphasise two aspects of the calibration obtained through Tuutti model.

Firstly, the *Difference Index* decreases as the rate of the Tuutti calibration increases. This aspect is easy predictable since the absence of Tuutti model calibration in DSS is one of the main differences of the two methods, and by increasing k , the DSS methodology become more similar to Gde-UnB method.

Secondly, the *Sensitivity Index* increases as k increases. This result is particular interesting and points out that the robustness of the DSS result decreases due to the Tuutti calibration.

It is worth noting that having low values of the *Difference Index* is a positive feature whereas having high values of *Sensitivity Index* is a negative feature. Therefore, an optimal point is not immediately identifiable in the graphs of Fig. 15. Consequently, two criteria are used to find the optimal calibration values of k : the *Sensitivity Index* has to increase slowly with k and the *Difference Index* has to decrease rapidly with k .

The best point is individuated where the curves of *Sensitivity Index* and the *Difference Index* exhibit the minimum values of derivative (Sangiorgio et al. 2018c). Indeed, after this point, by further increasing k , the sensitivity increases more rapidly (rapidly worsening the result) and the difference decrease more slowly (slowly improving the result).

The minimization of the two derivatives provides the values of $k = 0.33$. Table 9 shows the weights of DSS KPIs calibrated with $k = 0.33$.

Table 9. KPIs calibrated with the Tuutti with $k = 0.33$.

Weights of criteria and alternatives after calibration with Tuutti 33%																									
λ_1	$w_{1,1}$	$w_{1,2}$	$w_{1,3}$	$w_{1,4}$	$w_{1,5}$	$w_{1,6}$	$w_{1,7}$	$w_{1,8}$	$w_{1,9}$	$w_{1,10}$	$w_{1,11}$	$w_{1,12}$	$w_{1,13}$	$w_{1,14}$	$w_{1,15}$	$w_{1,16}$	$w_{1,17}$	$w_{1,18}$	$w_{1,19}$	$w_{1,20}$	$w_{1,21}$	$w_{1,22}$			
0.1	10	9.1	7.9	6.1	6.1	6.1	6.1	6.1	6.1	6.1	5.5	2.4	2.2	2.2	1.7	1.7	1.7	1	1	1	1	1			
λ_2	$w_{2,1}$	$w_{2,2}$	$w_{2,3}$	$w_{2,4}$	$w_{2,5}$	$w_{2,6}$	$w_{2,7}$	$w_{2,8}$	$w_{2,9}$	$w_{2,10}$															
0.43	10.0	8.3	6.8	5.5	4.5	3.6	2.8	2.1	1.4	0.7															
λ_3	$w_{3,1}$	$w_{3,2}$	$w_{3,3}$	$w_{3,4}$	$w_{3,5}$	$w_{3,6}$	$w_{3,7}$	$w_{3,8}$	$w_{3,9}$	$w_{3,10}$	$w_{3,11}$	$w_{3,12}$	$w_{3,13}$	$w_{3,14}$	$w_{3,15}$	$w_{3,16}$	$w_{3,17}$	$w_{3,18}$	$w_{3,19}$	$w_{3,20}$	$w_{3,21}$	$w_{3,22}$	$w_{3,23}$	$w_{3,24}$	$w_{3,25}$
0.44	2.1	3.9	8.8	2.1	4.4	9.1	2.1	3.9	3.9	2.4	8.3	9.1	5.1	5.1	10.0	1.4	2.1	3.9	0.7	3.5	3.5	0.7	0.7	3.5	3.5
λ_4	$w_{4,1}$	$w_{4,2}$	$w_{4,3}$	$w_{4,4}$	$w_{4,5}$	$w_{4,6}$	$w_{4,7}$	$w_{4,8}$	$w_{4,9}$	$w_{4,10}$															
0.03	10	6.2	1.1																						

Sensitivity Index=0.23; Difference Index=0.17;

5.7 Results of the case studies

In order to show the results of the case studies, the formulation of proposed DSS KPIs calibrated at 33% is used in comparison with the GDE-UnB.

Fig. 46 shows the degradation of the class of components for the case study of “Lopopolo” obtained by using formulation (3) and (19) in the calibrated KPIs and GDE methods, respectively. Fig. 47 shows the *structure index* for all the case studies.

These plots show the similarity between the two results. The trend of the result is very similar for the two methods and the higher values obtained in the GDE methodology are due to a different normalization of the formulas (2-3) and (18-19)).

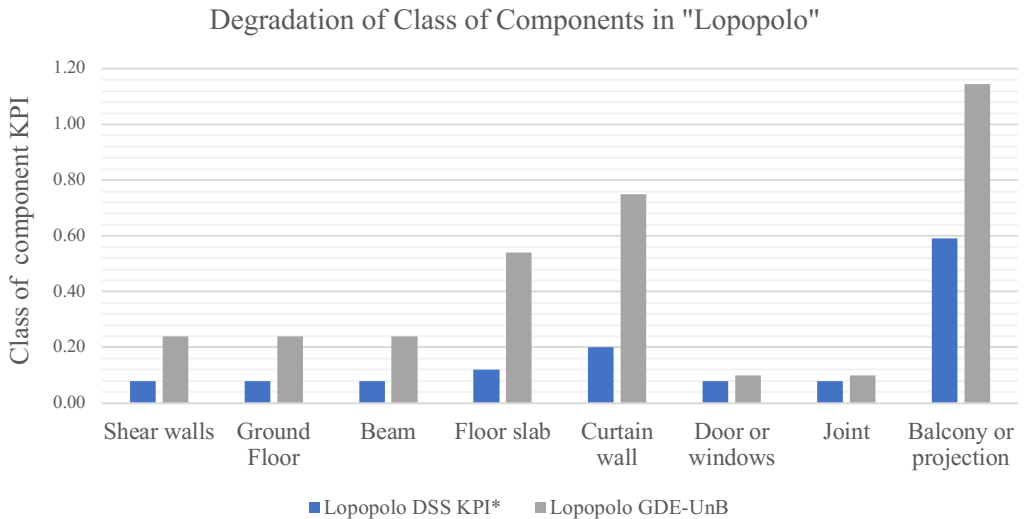


Fig. 46. - Case Study of “Cirielli” school building: KPI for the degradation of the class of component

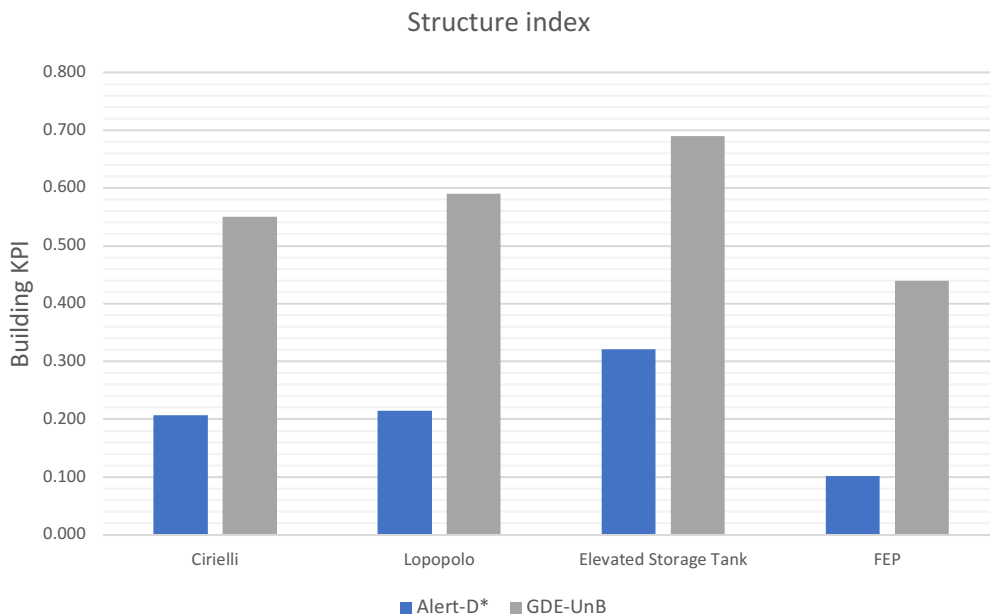


Fig. 47. - Case study result: structure indexes of all the case study

In particular, it is possible to point out the following considerations. The most damaged structure is the “Elevated Storage Tank” and the building considered, overall, in good conditions is the “FEP”.

According to the analysis, the class of components “floor slab” in the “Elevated Storage Tank” is subject to severe degradation and also columns and beams are in an initial phase of reinforced concrete rebar oxidation. The school Buildings “Cirielli” and “Lopopolo” are in very similar conditions. In these buildings, the class of components is in good condition but a few pathologies can be considered serious. Therefore, globally, the schools are in a medium state of conservation but the *class of component* index and the *single damage* index show the dangerousness of a few heavy pathologies.

On the contrary, “FEP” building has a generalized slight degradation and all the classes of components are in good or medium condition. In this building, the number of detected pathologies is high but the building it is large and overall in better condition. The Matrices of Damages of the case studies are shown in attachment 2

6 TEST SITE: LARGE-SCALE APPLICATION OF THE DSS

In order to assess the KPIs and the large-scale DSS applicability to different types of RC constructions, the Mediterranean coastline in Spain has been chosen, in particular the *Test Site* is focused on the Valencian coast. The rationality of this choice is due to the diversity of typology and exposure to aggressive environments of the buildings present in this area. In particular in the coast of Valencia it is possible to consider RC constructions of very different sizes and subject to different levels of marine atmosphere exposures.

6.1 The coast of Valencia

The Coast of Valencia is 440 km long and contains 65 townships, with the notable presence of multi-storey holiday-apartment blocks, which outnumber those used as permanent residences. Such coastline, bathed by the Mediterranean Sea has undergone a profound metamorphosis in the last 50 years, becoming a popular area for holiday homes (Menero & Garrido 2011). Since the late sixties, it has experienced a continual growth in tourism which has greatly multiplied the number of buildings constructed in the area, especially of those that could be described as weekend or holiday homes. This effect was increased during the periods of the building expansion as occurred between 1968 and 1973.

The building typology used in these areas is the apartment block, although there are also many terraced houses. The structure of the buildings is usually made with RC frames and generally precast joist slabs. The RC structure is often visible (mainly on outer walls and open-plan ground floors) or given a thin covering of mortar (Moreno et al. 2015). These buildings are therefore highly exposed to the aggressive agents in the marine atmosphere (Adam et al. 2016, Moradian et al. 2014). The corrosion of the reinforcement by the sea atmosphere is one of the main causes of the deterioration of RC (Angst, 2009, Jin et al. 2016, Pradhan 2014).

The types of construction and their structural characteristics have not been suitably

adapted to the aggressive marine atmosphere endemic to the area because of the rapid growth of tourism in Spain in the last 50 years. In fact, the primary design considerations of these buildings have concentrated on other aspects, such as making the most of the sea view and the context of the beach. Following such criteria, the buildings are generally designed with large terraces, flat roofs and enough height to provide good views of the sea. However, most of these buildings near the coast and used by holidaymakers are highly exposed to the marine atmosphere, and as most of them have RC structures, the damage caused by this phenomenon is quite severe.

All the factors mentioned above are taken into consideration in the planning *Test Site* with the purpose of quantify the buildings damages and to identify the worst condition structures in three cities on the coast of Valencia.

6.2 Data acquisition on the Valencia coast

The DSS methodology is applied to 131 buildings in Valencia's coastal region (Spain) (Fig. 48).



Fig. 48. - Location of Valencia in Spain and Europe

In particular, the DSS methodology is applied to multi-storey buildings with RC slabs and frames in three different towns. The cities have been chosen for their different of urban plans, which can be described as follows:

- 53 buildings are analysed in *El Perellonet*, a town with a linear development along the beach-front. This type of development is characterised by parallel rectangular plots close to the coastline. Within these plots the buildings do not follow any defined pattern. The blocks have more than 10 storeys with large shared areas.
- 62 buildings are analysed in *Puebla de Farnals*, which has a rectangular residential area with several rows of houses and a small port. The buildings on the beach front are small villas that shield the multi-storey buildings in the second and third line.
- 16 buildings are analysed in *Playa Puig*. This town is characterised by irregular development, with multi-storey buildings along the beach front shielding larger buildings further back. The buildings in this town are generally further from the sea than in other towns on the Valencia coast.

Fig.49 shows the technical map of the 3 towns chosen for the test site.



Fig. 49. - Technical map of the 3 towns studied

6.3 Analysis of building degradation on the Valencia coast

In order to assess the DSS procedure and the calibrated KPIs the Analysis of building degradation on the Valencia coast the three methodological phases of the DSS are applied.

Firstly, the *Data Acquisition Phase*, is performed, the *Building Registry Tabs* are realized by recover basic information about multi-storey building under investigation and the reports of damages are elaborated in the QDP. Fig. 50 shows the *Registry Tabs* of the building 3 in El Perellonet. Secondly, in the *Data Processing Phase* all the report are stored in *Diagnostic Tabs* and *Matrix of Damage*. Finally, during *Diagnostic Phase* the reports are analyzed and KPIs are evaluated.

In particular, for each investigated building and for every building component the damages surveyed is evaluated by Eq. (1), while Cr is obtained by Eq. (2). Fig. 51 shows

After evaluating all the Cr for all the components e of every structure, the global condition of the buildings BCr is obtained by Eq. (5). The *Matrix of Damage* shows the classification of damage in *building 51* and shows that $BCr=8.3$ (Fig. 52). The matrix is a useful graphical interface for an immediate overview of the types of damage affecting the building. In the cell of the matrix (Fig. 52) the number of the damage items detected with respect to the component and the critical type are indicated. It is worth noting that the CCr of the *Balconies or projections* component is equal to 9; this indicator suggests that the whole class of components has medium or serious damage (Fig. 52).

Fig. 52. - *Matrix of damage*, Damage overview and condition ratings of building 51 in El Perellonet

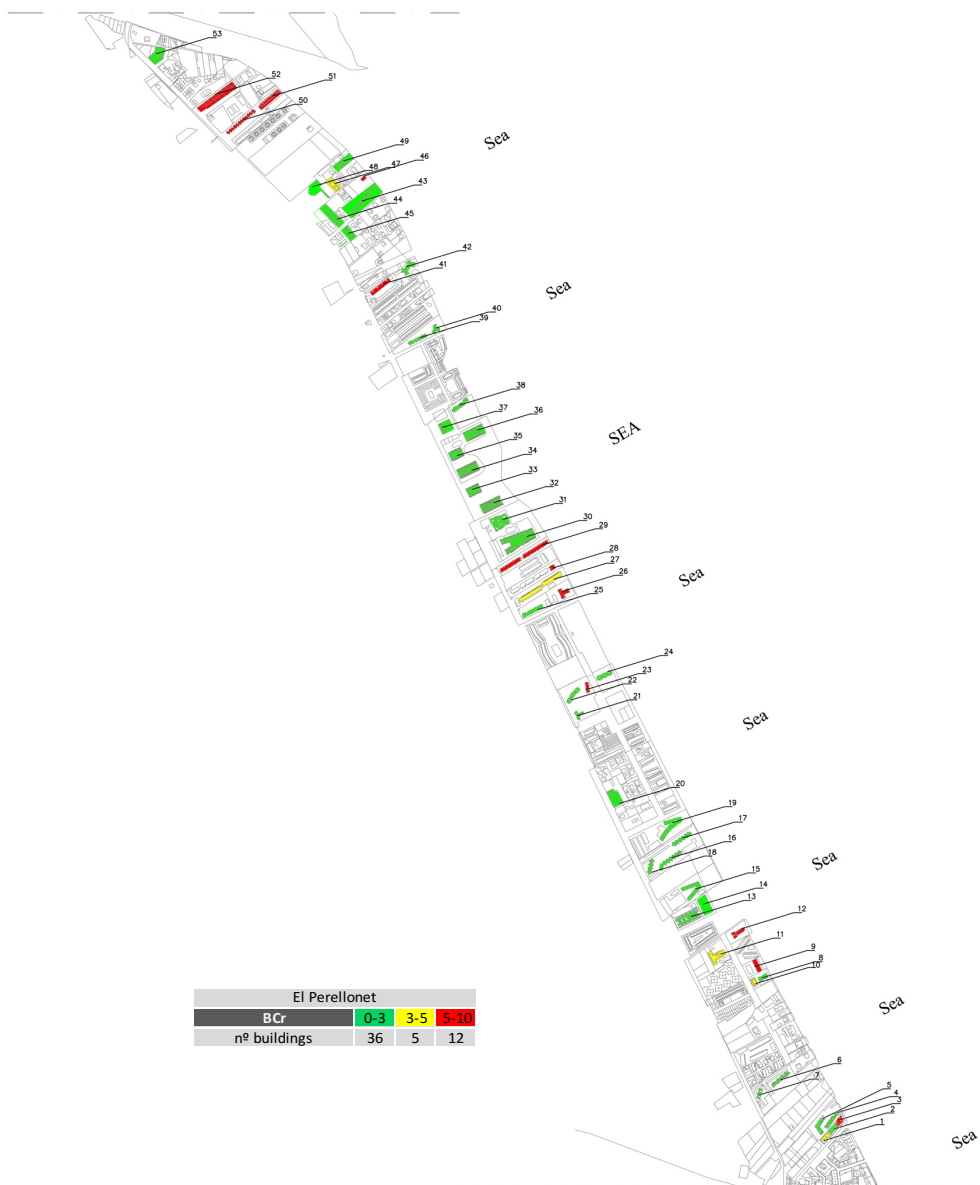


Fig. 53. - Damage map of *El Perellonet*



Fig. 54. - Damage map of *Playa Puebla de Farnals*

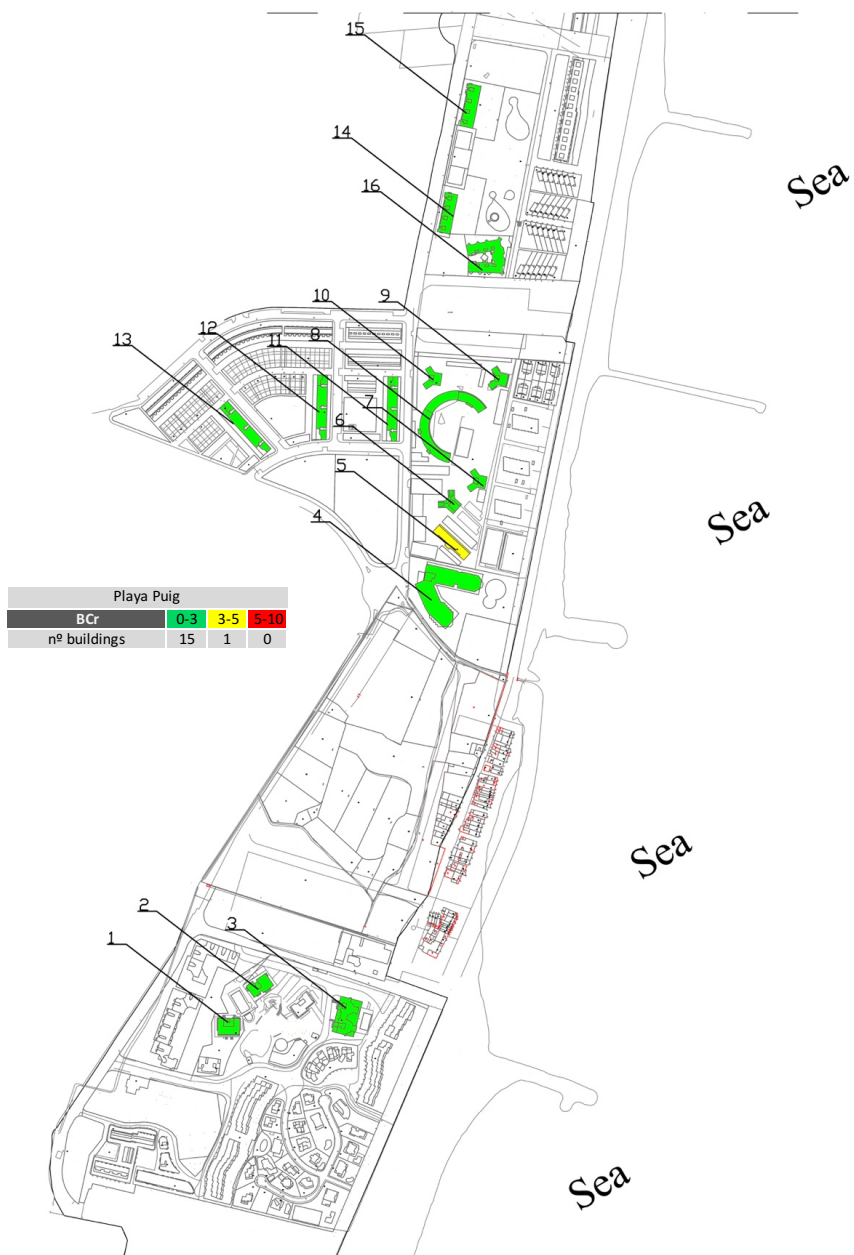


Fig. 55. - Damage map of *Playa Puig*

The most damaged building with priority of intervention are building 53 and 62 in *Playa Puebla de Farnals*, and building 3, 9, 12, 22, 26, 28, 29, 41, 46, 50, 51 and 52 in *El Perellonet*, shown in red in the related Damage map of the City. In *Playa Puig* there are no buildings in serious condition.

The DSS procedure provides an overview of the most damaged buildings and indicates the most dangerous damages through the *Diagnostic Tabs*. In particular the *BCr* provide information regarding building globally in worse conditions. Furthermore, by analysing the KPI of *Cr* it is possible to identify buildings that may have serious damage even if their global condition is good. In addition, it is possible to extract information concerning the degradation of the investigated cities. Fig. 56 shows the percentage of damaged buildings in the three towns according to the five defined ranges. *El Perellonet*, in which most of the buildings are on the beach front, had the highest number of seriously damaged buildings with more than 10 percent of buildings in medium and heavy condition.

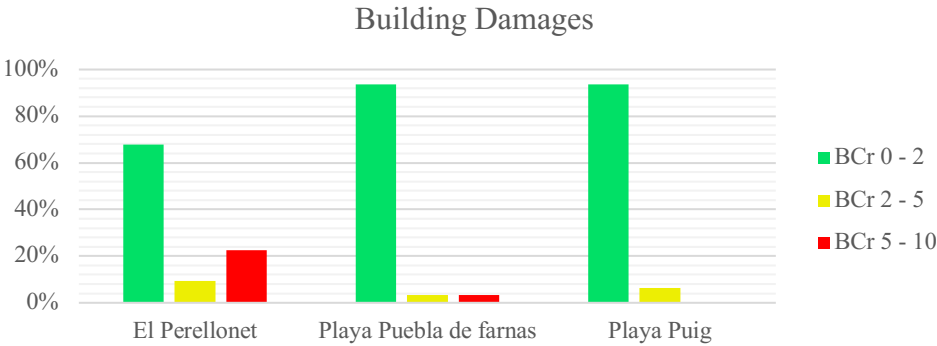


Fig. 56. - Damaged building distribution in the 3 towns studied

Finally, within a large portfolio of buildings, the analysis allows to have an effective overview of the most damaged buildings. The methodology provides a prioritization of interventions to support the identification of an effective maintenance strategy. Moreover, the continuous data flow and KPIs updating allows a monitoring of the structures. A warning signal is provided by the DSS if some building damage overcome the

threshold values of safety (Fig. 26). In addition, the large amount of collected data are useful for the research purpose to analyse the buildings degradation on the Valencian coast in order to identify the most important involved phenomena, as described in the following section.

7 DISCUSSION AND RESULTS

The described DSS procedure is able to perform complex operations to support the technician's operation in the diagnostics and maintenance field. The method combines synergistically many techniques and technologies to be effective on a large scale. To this aim the system provides a set of functions described as follows: i) storage and classification of registry data; ii) large scale data acquisition supported by modern Information and Communication Technologies (ICT), iii) automatic calculation of 3 calibrated and optimized KPIs to quantify local and global structural damage, iv) classification of damages in specific matrices to display an overview of the building condition, v) identification of the most damaged buildings and warning signal.

All these functions can be used by architects, engineers, and interested stakeholders to improve management and maintenance and prioritize interventions. Beyond this, also researchers can use this tool to carry out complex analyses on a large scale. This section shows two practical examples of how the DSS can be applied for two different purpose: i) large-scale monitoring of school buildings with particular focus to the user safety, ii) carrying out complex analysis on a large scale to identify the most significant phenomena causing deterioration of buildings on the coast of Valencia.

7.1 The specific case of the R.C. school building user safety

This section shows how the system can be adaptable to different problems. In particular the structural damage KPIs are improved to consider the potential damage of the structural degradation to school users. To this aim an improvement of the degradation analysis formulation of the DSS is set and used to simplify such operations and to detect the criticalities that can compromise user safety or building usability.

Analogously to the case of structural degradation, the first step of *O-AHP* applied to the DSS for R.C. school buildings consists in the *Structure of the Problem*. The following

sets of criteria and alternatives are defined:

- $C' = \{i' = 1, \dots, m'\}$, set of criteria of cardinality m' ;
- $B'_i = \{b'_{ij} \mid j = 1, \dots, \alpha'_i\}$, set of α'_i alternatives associated to each criterion $i \in C'$.

In particular, the safety performance level is affected by individual damaged components and by the local collapse of the building components (Uva, G. et al 2016, Sangiorgio et al. 2016, Sangiorgio 2015). In order to consider such condition in the analysis new criteria are added in the structuring of the problem as described below.

The goal is the semeiotic assessment of *building safety performance level* and the problem is structured in $m=6$ criteria: i) *Damaged component*, i.e. the importance of the damaged component; ii) *Damage severity*, i.e. the gravity of the damage; iii) *Damage progress*, i.e., the damage typology aptitude to rapidly worsen; iv) *Damage extension*, i.e. the damage extension in relation with the component dimension expressed in percentage; v) *Height above walking surface of the criticality*, i.e., the risk of falling broken components; vi) *Room crowding*, i.e., the potential number of people present in the room where the damage is detected.

Moreover, a set of alternatives is associated to each criterion as shown in detail in Fig. 57 with $\alpha'_1 = 16$, $\alpha'_2 = 26$, $\alpha'_3 = 26$, $\alpha'_4 = 10$, $\alpha'_5 = 5$ and $\alpha'_6 = 9$.

The second step of *O-AHP* provides the weights that are defined as follows:

- v'_i is the weight associated to criterion $i \in C'$;
- w'_{ij} is the weight associated to alternative $b'_{ij} \in B'_i$ of criterion $i \in C'$.

The *O-AHP* is performed by obtaining seven *Judgment Matrices of* six matrices identify the weights w'_{ij} of the alternatives associated to the six criteria and one matrix identifies the weight v'_i of each criterion. Fig. 57 shows the association of the alternatives b'_{ij} to the weights w'_{ij} , and of the criterion i to the weight v'_i . As an example, the criterion $i = 1$, i.e., *Damaged component*, is associated to the weight v'_1 , and $\alpha'_1 =$

16 alternatives are defined. For example, the first alternative b'_{11} of the first criterion is “shear wall” and the associate weight is w'_{11} .

Goal	BUILDING SAFETY PERFORMANCE LEVEL					
Criteria	Damaged component w'_1	Damage severity w'_2	Damage progressivity w'_3	Damage extension w'_4	Height above walking surface of the criticality w'_5	Room crowding w'_6
Alternatives	Shear wall $w'_{1,1}$ Column $w'_{1,2}$ Foundation level $w'_{1,3}$ Beam $w'_{1,4}$ Braced frame $w'_{1,5}$ Floors or staircase $w'_{1,6}$ Roof $w'_{1,7}$ Catwalks or elevator $w'_{1,8}$ Curtain wall $w'_{1,9}$ Balcony $w'_{1,10}$ Internal-External wall $w'_{1,11}$ False ceiling $w'_{1,12}$ Doors and windows fixture $w'_{1,13}$ Ground floor $w'_{1,14}$ Joint between elements $w'_{1,15}$ Sunshade or projection $w'_{1,16}$	*Cracks caused by rebar oxidation $w'_{2,1}$ *Spalling $w'_{2,2}$ *Heavy concrete spalling $w'_{2,3}$ Thin cracks $w'_{2,4}$ Medium cracks $w'_{2,5}$ Wide or active cracks $w'_{2,6}$ Defects at junctions $w'_{2,7}$ Detachment of elements $w'_{2,8}$ Brick blocks falling down $w'_{2,9}$ Component deformation $w'_{2,10}w'_{2,11}$ Walls or elements leaning out of vertical $w'_{2,12}$ Small foundation settlement $w'_{2,13}$ Medium foundation settlement $w'_{2,14}$ Heavy foundation settlement $w'_{2,15}$ Decay phenomena (e.g. wet area...) $w'_{2,16}$ Cracking of plaster or veneer $w'_{2,17}$ Detachment of plaster or veneer $w'_{2,18}$ Detachment of heavy veneer $w'_{2,19}$ **Corrosion or oxidation of steel element $w'_{2,20}$ **Yielding $w'_{2,21}$ **Corrosion or oxidation with section reduction $w'_{2,22}$ ***Mould or marcescence $w'_{2,23}$ ***Biological insect attack $w'_{2,24}$ ***Mould or marcescence and section reduction $w'_{2,25}$ ***Biological insect attack and section reduction $w'_{2,26}$	*Cracks caused by rebar oxidation $w'_{3,1}$ *Spalling $w'_{3,2}$ *Heavy concrete spalling $w'_{3,3}$ Thin cracks $w'_{3,4}$ Medium cracks $w'_{3,5}$ Wide or active cracks $w'_{3,6}$ Defects at junctions $w'_{3,7}$ Detachment of elements $w'_{3,8}$ Brick blocks falling down $w'_{3,9}$ Component deformation $w'_{3,10}$ Excessive deflection, deformations $w'_{3,11}$ Walls or elements leaning out of vertical $w'_{3,12}$ Small foundation settlement $w'_{3,13}$ Medium foundation settlement $w'_{3,14}$ Heavy foundation settlement $w'_{3,15}$ Decay phenomena (e.g. wet area...) $w'_{3,16}$ Cracking of plaster or veneer $w'_{3,17}$ Detachment of plaster or veneer $w'_{3,18}$ Detachment of heavy veneer $w'_{3,19}$ **Corrosion or oxidation of steel element $w'_{3,20}$ **Yielding $w'_{3,21}$ **Corrosion or oxidation with section reduction $w'_{3,22}$ ***Mould or marcescence $w'_{3,23}$ ***Biological insect attack $w'_{3,24}$ ***Mould or marcescence and section reduction $w'_{3,25}$ ***Biological insect attack and section reduction $w'_{3,26}$	100% $w'_{4,1}$ 90% $w'_{4,2}$ 80% $w'_{4,3}$ 70% $w'_{4,4}$ 60% $w'_{4,5}$ 50% $w'_{4,6}$ 40% $w'_{4,7}$ 30% $w'_{4,8}$ 20% $w'_{4,9}$ 10% $w'_{4,10}$	Greater than 4m $w'_{5,1}$ Between 3m and 4m $w'_{5,2}$ Between 2m and 3m $w'_{5,3}$ Between 1,5m and 2m $w'_{5,4}$ Less than 1,5 $w'_{5,5}$	Room-Laboratory $w'_{6,1}$ Gym $w'_{6,2}$ Outdoor pedestrian area $w'_{6,3}$ Entrance or Hallway $w'_{6,4}$ Staircase $w'_{6,5}$ Toilette $w'_{6,6}$ Forecourt $w'_{6,7}$ Office $w'_{6,8}$ Storeroom $w'_{6,9}$

Note: *R.C. pathologies; **Steel pathologies; ***Wood pathologies

Fig. 57. - Structure of the Problem: weight criteria and alternatives for the building safety performance level

Fig. 58 shows the *Judgment Matrix* corresponding to the criterion of *Room Crowding*. This matrix is generated referring to the regulatory data of the Italian Building Code (Code 2008) with regard to the service loads and importance classes of buildings (CEN 2015) and the assigned *Judgement Ranges* are showed in Fig. 59.

Room crowding	Room or Laboratory	Gym	Outdoor pedestrian area	Entrance or Hallway	Staircase	Toilette	Forecourt	Office	Storeroom	$w'_{6,j}$	CR
Room-Laboratory	1.0	1.0	1.8	2.4	2.4	4.7	3.9	3.9	9.0	10.0	0.026
Gym	1.0	1.0	2.0	2.4	2.4	4.6	3.8	3.4	9.0	9.8	
Outdoor pedestrian area	0.6	0.5	1.0	1.8	1.8	3.0	2.5	2.3	9.0	6.4	
Entrance or Hallway	0.4	0.4	0.6	1.0	1.0	2.5	1.7	1.5	6.3	4.3	
Staircase	0.4	0.4	0.6	1.0	1.0	3.0	3.0	1.7	7.3	4.9	
Toilette	0.2	0.2	0.3	0.4	0.3	1.0	1.0	1.0	3.2	2.1	
Forecourt	0.3	0.3	0.4	0.6	0.3	1.0	1.0	1.0	6.9	2.6	
Office	0.3	0.3	0.4	0.7	0.6	1.0	1.0	1.0	6.9	2.9	
Storeroom	0.1	0.1	0.1	0.2	0.1	0.3	0.1	0.1	1.0	0.7	

Fig. 58. - *Judgment Matrix* for the room crowding criteria weighting.

The solution of the MP (8a-b) provides the matrix of the Criterion of *Room Crowding*, and the solution of equation (1) gives the weights. The last column in Fig. 58 shows the value of the *CR* that satisfies the Saaty consistency requirement ($CR < 0.1$).

i^{th} element	K_{ij}^L	a_{ij}	K_{ij}^U	j^{th} element
Room-Laboratory	$1.0 \leq$	$a_{1,2}$	≤ 1.1	Gym
Room-Laboratory	$1.8 \leq$	$a_{1,3}$	≤ 1.9	Outdoor pedestrian area
Room-Laboratory	$2.4 \leq$	$a_{1,4}$	≤ 2.6	Entrance or Hallway
Room-Laboratory	$2.4 \leq$	$a_{1,5}$	≤ 2.6	Staircase
Room-Laboratory	$4.7 \leq$	$a_{1,6}$	≤ 4.9	Toilette
Room-Laboratory	$3.9 \leq$	$a_{1,7}$	≤ 4.1	Forecourt
Room-Laboratory	$3.9 \leq$	$a_{1,8}$	≤ 4.1	Office
Room-Laboratory	$9.0 \leq$	$a_{1,9}$	≤ 9.0	Storeroom
Gym	$2.0 \leq$	$a_{2,3}$	≤ 2.0	Outdoor pedestrian area
Gym	$2.4 \leq$	$a_{2,4}$	≤ 2.6	Entrance or Hallway
Gym	$2.4 \leq$	$a_{2,5}$	≤ 2.6	Staircase
Gym	$4.5 \leq$	$a_{2,6}$	≤ 4.6	Toilette
Gym	$3.7 \leq$	$a_{2,7}$	≤ 3.9	Forecourt
Gym	$3.4 \leq$	$a_{2,8}$	≤ 3.6	Office
Gym	$9.0 \leq$	$a_{2,9}$	≤ 9.0	Storeroom
Outdoor pedestrian area	$1.8 \leq$	$a_{3,4}$	≤ 2.2	Entrance or Hallway
Outdoor pedestrian area	$1.8 \leq$	$a_{3,5}$	≤ 2.2	Staircase
Outdoor pedestrian area	$3.0 \leq$	$a_{3,6}$	≤ 3.1	Toilette
Outdoor pedestrian area	$2.5 \leq$	$a_{3,7}$	≤ 2.5	Forecourt
Outdoor pedestrian area	$2.2 \leq$	$a_{3,8}$	≤ 2.4	Office
Outdoor pedestrian area	$9.0 \leq$	$a_{3,9}$	≤ 9.0	Storeroom
Entrance or Hallway	$1.0 \leq$	$a_{4,5}$	≤ 1.0	Staircase
Entrance or Hallway	$2.5 \leq$	$a_{4,6}$	≤ 2.5	Toilette
Entrance or Hallway	$1.6 \leq$	$a_{4,7}$	≤ 1.7	Forecourt
Entrance or Hallway	$1.4 \leq$	$a_{4,8}$	≤ 1.6	Office
Entrance or Hallway	$6.2 \leq$	$a_{4,9}$	≤ 6.3	Storeroom
Staircase	$3.0 \leq$	$a_{5,6}$	≤ 3.0	Toilette
Staircase	$3.0 \leq$	$a_{5,7}$	≤ 3.0	Forecourt
Staircase	$1.5 \leq$	$a_{5,8}$	≤ 2.0	Office
Staircase	$6.5 \leq$	$a_{5,9}$	≤ 7.5	Storeroom
Toilette	$1.0 \leq$	$a_{6,7}$	≤ 1.0	Forecourt
Toilette	$1.0 \leq$	$a_{6,8}$	≤ 1.0	Office
Toilette	$3.0 \leq$	$a_{6,9}$	≤ 3.4	Storeroom
Forecourt	$1.0 \leq$	$a_{7,8}$	≤ 1.0	Office
Forecourt	$6.9 \leq$	$a_{7,9}$	≤ 7.1	Storeroom
Office	$6.9 \leq$	$a_{8,9}$	≤ 7.1	Storeroom

Fig. 59. - Judgement Ranges assigned for the alternatives of the criterion "*Room Crowding*".

Moreover, Fig. 60 shows all the criteria and alternatives *weights* obtained by applying the *O-AHP* methodology to the specific case of the safety of R.C. school building. Such tabulated weights can be used in the formulation of the KPIs analogously to the structural degradation ones.

Weights of criteria and alternatives																																									
v_1^1	$w'_{1,1}$	$w'_{1,2}$	$w'_{1,3}$	$w'_{1,4}$	$w'_{1,5}$	$w'_{1,6}$	$w'_{1,7}$	$w'_{1,8}$	$w'_{1,9}$	$w'_{1,10}$	$w'_{1,11}$	$w'_{1,12}$	$w'_{1,13}$	$w'_{1,14}$	$w'_{1,15}$	$w'_{1,16}$																									
0.09	10.0	9.9	7.3	5.8	5.8	3.4	3.6	1.7	1.7	2.0	0.7	0.7	0.7	0.8	0.7	2.0																									
v_2^1	$w'_{2,1}$	$w'_{2,2}$	$w'_{2,3}$	$w'_{2,4}$	$w'_{2,5}$	$w'_{2,6}$	$w'_{2,7}$	$w'_{2,8}$	$w'_{2,9}$	$w'_{2,10}$	$w'_{2,11}$	$w'_{2,12}$	$w'_{2,13}$	$w'_{2,14}$	$w'_{2,15}$	$w'_{2,16}$	$w'_{2,17}$	$w'_{2,18}$	$w'_{2,19}$	$w'_{2,20}$	$w'_{2,21}$	$w'_{2,22}$	$w'_{2,23}$	$w'_{2,24}$	$w'_{2,25}$	$w'_{2,26}$															
0.32	1.0	4.0	7.0	1.0	3.5	10.0	1.0	4.0	9.9	2.0	4.0	10.0	1.0	1.0	6.0	1.0	1.0	4.0	9.9	1.0	3.5	6.5	1.0	1.0	6.5	6.5															
v_3	$w'_{3,1}$	$w'_{3,2}$	$w'_{3,3}$	$w'_{3,4}$	$w'_{3,5}$	$w'_{3,6}$	$w'_{3,7}$	$w'_{3,8}$	$w'_{3,9}$	$w'_{3,10}$	$w'_{3,11}$	$w'_{3,12}$	$w'_{3,13}$	$w'_{3,14}$	$w'_{3,15}$	$w'_{3,16}$	$w'_{3,17}$	$w'_{3,18}$	$w'_{3,19}$	$w'_{3,20}$	$w'_{3,21}$	$w'_{3,22}$	$w'_{3,23}$	$w'_{3,24}$	$w'_{3,25}$	$w'_{3,26}$															
0.04	8.3	8.3	8.3	2.4	2.4	10.0	2.4	2.4	2.4	2.1	2.1	10.0	2.0	2.0	2.0	4.4	4.4	6.7	6.7	4.8	4.8	4.8	2.2	2.2	2.2	2.2															
v_4	$w'_{4,1}$	$w'_{4,2}$	$w'_{4,3}$	$w'_{4,4}$	$w'_{4,5}$	$w'_{4,6}$	$w'_{4,7}$	$w'_{4,8}$	$w'_{4,9}$	$w'_{4,10}$																															
0.11	10.0	9.0	8.0	7.0	6.0	5.0	4.0	3.0	2.0	1.0																															
v_5	$w'_{5,1}$	$w'_{5,2}$	$w'_{5,3}$	$w'_{5,4}$	$w'_{5,5}$																																				
0.28	10.0	6.9	2.9	0.8	0.8																																				
v_6	$w'_{6,1}$	$w'_{6,2}$	$w'_{6,3}$	$w'_{6,4}$	$w'_{6,5}$	$w'_{6,6}$	$w'_{6,7}$	$w'_{6,8}$	$w'_{6,9}$																																
0.16	10.0	9.8	6.4	4.3	4.9	2.1	2.6	2.8	0.7																																

Fig. 60. - Obtained weights to perform a “semeiotic assessment in R.C. buildings”

7.1.1 Sensitivity Analysis for R.C. school building user safety

The final step of the procedure is the *Sensitivity Analysis* that verifies how the final results would change if the weights of the criteria were different. It also allows to understand how robust are the final KPIs and which criteria influence more the results. The sensitivity analysis is performed by changing the weights of the criteria and verifying how they modify the overall priorities of the alternatives (Butler et al. 1997, Triantaphyllou and Sánchez 1997).

In the proposed application, the main objective is not to assess the local ranking, but to provide the global weight distribution. Therefore, it is adopted the approach proposed by Hurley (2001) for the sensitivity analysis which enables the weights to be changed while maintaining the local ranking order. In such a method, the focus is on the global weight change and it is useful to evaluate the robustness of the result.

Let us consider a matrix of comparison A having elements a_{ij} , and let us define the additional matrices $\bar{A}$, where the elements $\bar{a}_{ij}$ are determined as follows:

$$\bar{a}_{ij} = a_{ij}^{\mu} \quad (27)$$

with $\mu \geq 0$. For $\mu = 1$, it holds $A = \bar{A}$; for $\mu > 1$, the resulting weights exhibit the same rank order but values are “exploded”; for $\mu < 1$, again the resulting weights have the same rank order but values are “imploded”. Such local weight variations allow assessing if the stability of the global weight and the overall rank order is preserved. Now, the matrices $\bar{A}$ are recalculated and weights are obtained by solving (1).

As an example, Table 10 shows the weights of the matrices of the *room crowding*

criterion for each $\mu \in \{0.5, 0.7, 0.9, 1, 1.1, 1.3, 1.5\}$.

To analyze the behavior of the global weights, the Cr_e associated to $H=200$ visual surveys (for $h=1, \dots, 200$) are evaluated according to (6).

Table 10. Variations of the weights of Room Crowding obtained by changing μ

Eigenvector	μ	0.5	0.7	0.9	1	1.1	1.3	1.5
	$w_{6,1}$	10	10	10	10	10	10	10
	$w_{6,2}$	9.93	9.91	9.89	9.84	9.87	9.84	9.82
	$w_{6,3}$	8.05	7.38	6.76	6.44	6.20	5.70	5.24
	$w_{6,4}$	6.58	5.57	4.71	4.34	3.99	3.38	2.87
	$w_{6,5}$	7.00	6.09	5.31	4.94	4.64	4.06	3.57
	$w_{6,6}$	4.63	3.41	2.51	2.14	1.86	1.37	1.02
	$w_{6,7}$	5.14	3.97	3.08	2.63	2.40	1.89	1.51
	$w_{6,8}$	5.37	4.20	3.30	2.93	2.60	2.07	1.65
	$w_{6,9}$	2.63	1.56	0.93	0.72	0.56	0.33	0.20
CR		0.086	0.068	0.019	0.020	0.069	0.208	0.420

For the sake of brevity, Fig. 61 shows the variation for the first 10 visual surveys with respect to the values of μ . It is evident that the trend is very regular, and there are few inversions in ranking, which are concentrated at the limit values. It should be considered, anyway, that the weights obtained for $\mu < 0.9$ and $\mu \geq 1.1$ are not reliable solutions since the associated matrices do not respect the CR consistency requirement $CR < 0.1$. In Table 10, the matrices obtained for $\mu = 1.3$ and $\mu = 1.5$ provide a consistency index $CR = 0.208$ and $CR = 0.420$, respectively. On the basis of these considerations, it is possible to state the reliability of the obtained global weights.

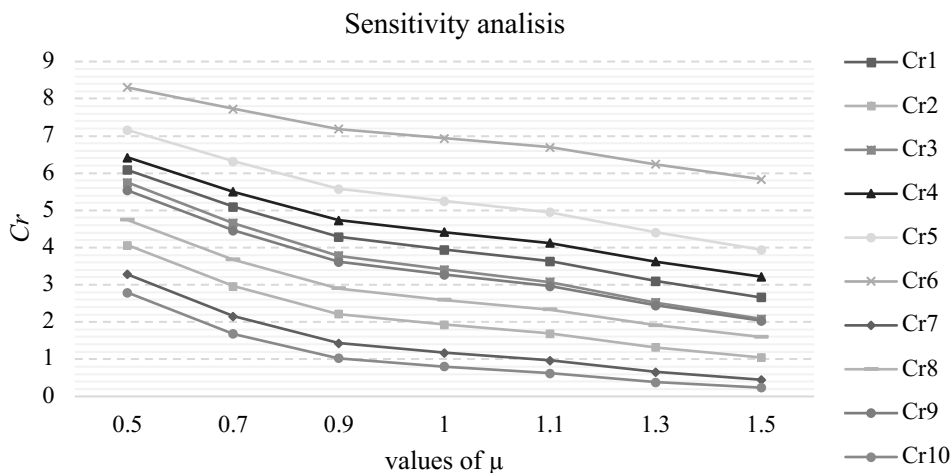


Fig. 61. - Sensitivity Analysis: plot of the weights' variations of Room Crowding by changing μ

7.1.2 Diagnostic tab for user safety

To provide an example of the result of the new KPIs, the *Diagnostic Sheet* (Fig. 62) shows the results of the questionnaire and the classification of the related information, such as criteria, alternatives and their associated weights, according to the proposed methodology.

Such sheets allow to display the photographic inspections and to check, and eventually correct, the information used to the automatic evaluation of the *Criticality Condition Rating*.

SC2	BUILDINGS		School Lopopolo		Diagnostic sheet			
	ADDRESS		Via Lazio 8		Photographic survey			
Decision Support System APP Report	id_report	data-photo	data-insert	data-creation	Knowledge Degree	username	id_structure	name
	e=44	24/04/17	24/04/17	24/04/17	Engineer	Valentino Mail ####	1	"Lopopolo"
				Criticality				
				Damaged component		Sunshade		2
				Damage extension		100%		10
				Height above walking surface of the criticality		Between 3 and 4m		6,9
				Room crowding		Outdoor pedestrian area		6,4
				Damage severity		Heavy concrete spalling		7
				Damage progressivity		Heavy concrete spalling		8,3
				Cr ⁴⁴		Local danger for building users		7,1
	Questionnaire					Answers		
	Where do you made the photo?					Out-door		
	Insert floor plan location of the problem					0		
	In which room do you photograph the criticality?					Outdoor pedestrian area		
	Which is the criticality height above walking surface?					Between 3m and 4m		
	What is exatly upstairs?					Building top		
	Which element do you photograph?					Sunshade or projection		
	Which is the damage extention compared with the element dimension?					100%		
Which is the damaged element material?					Concrete			
Which criticality did you photograph?					Heavy concrete spalling			

Fig. 62. - School Building "Lopopolo" Diagnostic Tab for building safety

7.2 The Alert-Ed Information System and APP

The KPIs developed for the school building safety performance level has been applied to realize the Alert-Ed Information System, a portal for intelligent monitoring of buildings and structures on a regional scale developed in collaboration with AutoLogS s.r.l.

Such tool makes easy to create a database of a group of buildings, and to archive related documents online. It also provides support to decisions in order to maintain the structure of the buildings in a safe condition.

The system is customizable based on user needs, on the typology, and on the use of the building stock managed by the customer.

The System is implemented as a web application that delivers the following support:

- 1) It offers the possibility to create and connect to an online database that lists technical and general information about buildings and structural assets.
- 2) It allows to collect information and report damage and critical issues of buildings, parts of them or other structures.

3) It supports decisions regarding identification and assessment of the extent of the building damage and criticality, and of the overall structural condition.

In particular an application software for mobile devices (APP) is developed for the operative system of “Android”. Such APP allow the user to send photographic survey and the answers of a questionnaire. The complexity of the questionnaire is automatically selected on the base of the knowledge of the User profile. The user can take more than one pictures and/or select images from the phone's library. The data can be sent when the questionnaire is answered and at least one photo is present in the report.

Fig.63 shows some screens of the APP representing the main functions: login; selection of structure; reporting by photo and questionnaire; sending data.

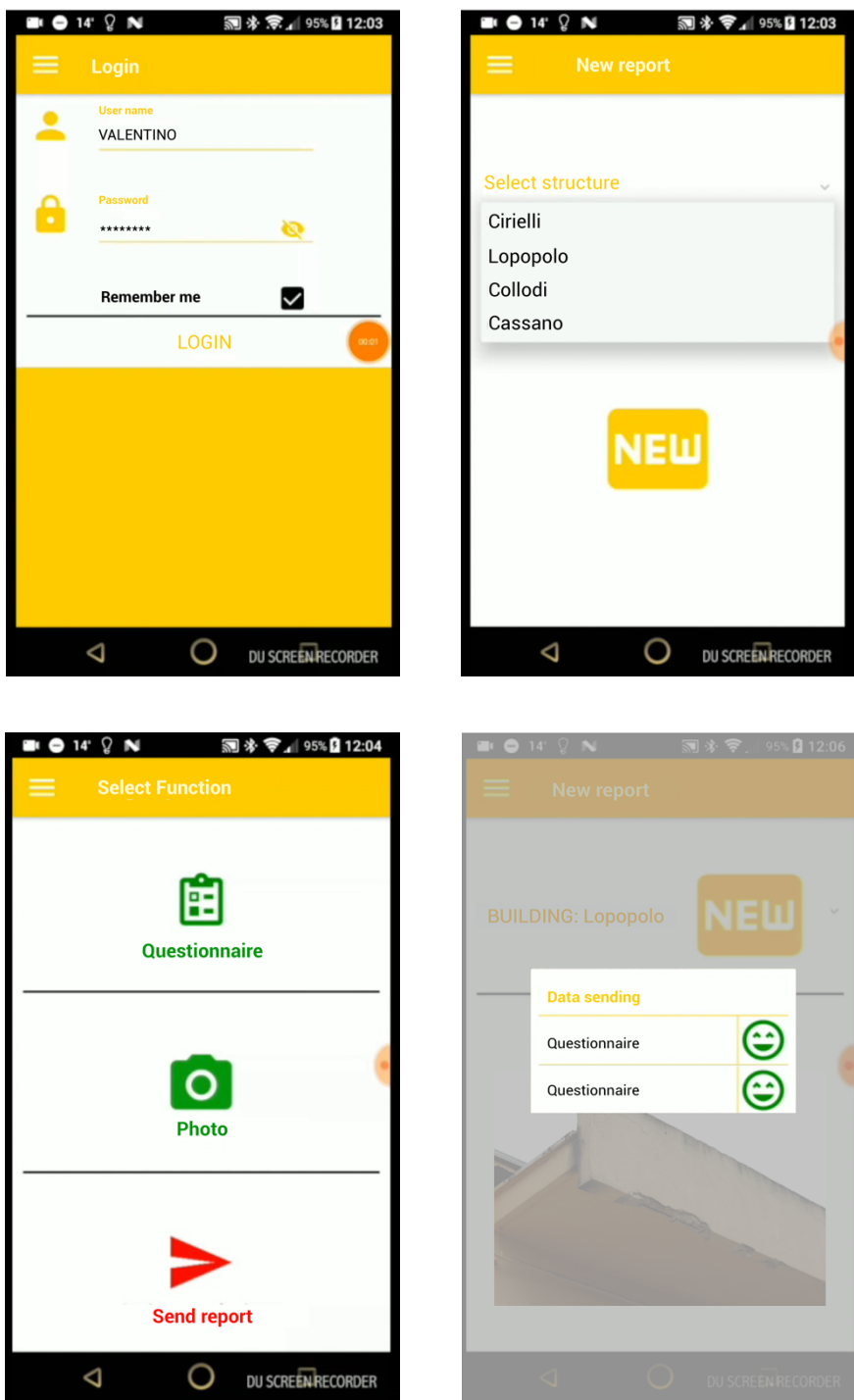


Fig. 63. - Screens of the APP

In addition, the web-based platform provides four functions displayable on the main screen (Fig. 64) and listed below: i) Add new building, ii) Registry Tabs, iii) Reports and iv) Summary Tabs.

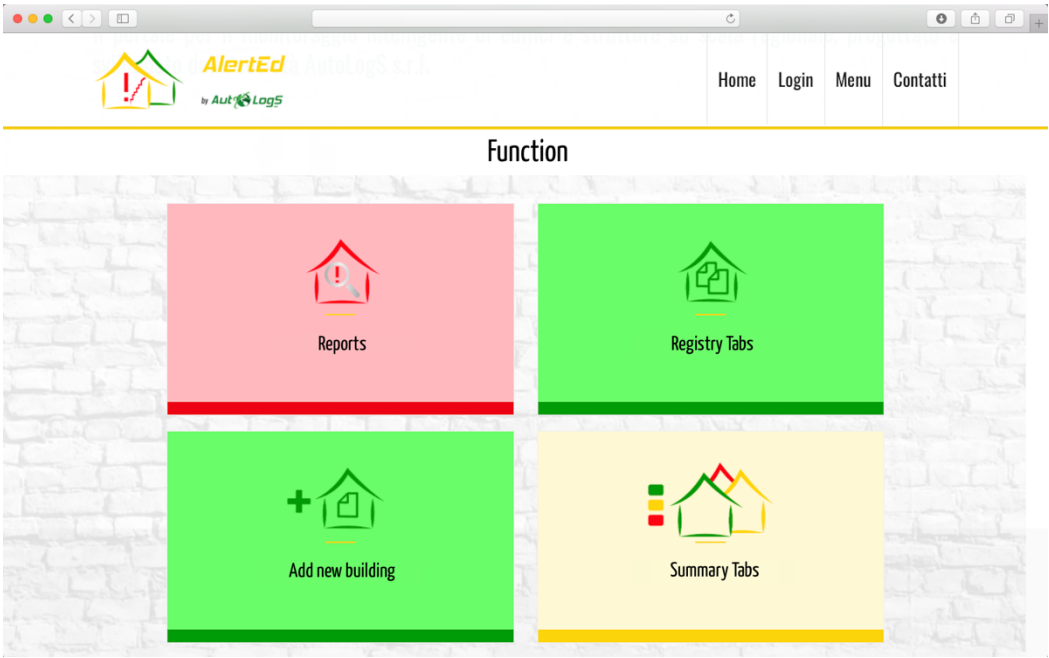


Fig. 64. - The main screen of the web-based platform “AlertEd”

-The first function is devoted to adding a new building to the platform. This utility is designed on the base of the *Registry Tab* and it is divided in nine set of data: general data, characteristic data, dimensional data, original project availability, intervention or modification, structural intervention, vulnerability assessment, reference technical code, and “other”. Fig. 65 shows the “Add new building” function. In particular the section of Characteristic data is displayed. Moreover, such page provides the possibility to upload and classify any file concerning building plan, report or analysis of the building.

AlertEd
by AutLog5

Home Login Menu Contatti

NEW REGISTRY TABS

General Data

- ✓ Characteristic Data
- ✓ Dimensional Data
- ✓ Original Projects Availability
- ✓ Interventions or modifications
- ✓ Structural interventions
- ✓ Vulnerability assessments
- ✓ Reference technical codes
- ✓ Other

Seismic Joint
☐ si ☒ no

Structural typology	☐ Steel ☐ Masonry ☐ Precast RC	☐ Wood ☒ Reinforced concrete
Curtain wall typology	☒ Brick ☐ Other	☐ Tuff
Staircase typology	☐ Reinforced concrete ☐ Wood ☒ Structural slab	☐ Steel ☐ Straight flight stairs
Slab typology	☐ Reinforced concrete ☒ Mixed concrete and brick ☐ Predalles	☐ Steel ☐ Mixed concrete and brick

Geomorphology Aquifer

Fig. 65. - Section of Characteristic data in the function “Add new building”.

-The “Registry Tab” function allow to display and modify all the data included during the “Add new building” function.

-In “Reports” function it is possible to view and correct all the damages, reported by the APP, of the buildings registered on the platform. This tab allows to filter all the received damages on the base of 3 criteria: i) name of the building; ii) date range of the report receipt; iii) performed revision.

Fig.66 shows one of the *Diagnostic Tabs* obtained by filter all data by the name of the building “Collodi”, and in the range of data between 04/09/2018 and 04/11/2018. In particular the *Diagnostic Tabs* of Fig.66 shows the damage surveyed in the school Collodi, by a certified user (user with specific competences in the building field) and not revised from a Technician. The diagnostic tab displays the characteristic data and the *condition rating* of the component for correction or validation.

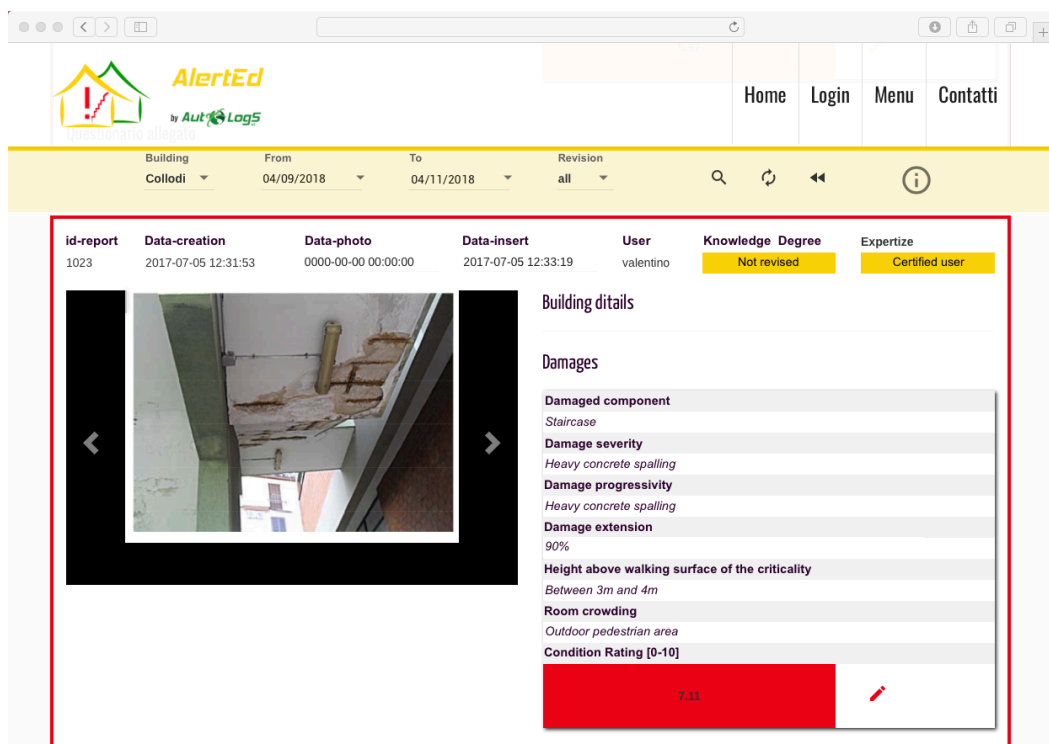


Fig. 66. - Diagnostic tab in the AlertEd web-based platform.

-Finally, “Summary Tabs” function is devoted to have an overview of damages and criticalities of the buildings registered on the platform (Fig. 67). In this function it is possible to sort the investigated buildings by the three KPIs in order to perform a quick comparison of the building’s conditions. This system supports the technician in identifying buildings that require detailed investigation and maintenance bringing together the personal experience and the condition rating obtained by the huge amount of available data.

Fig. 67 shows the resulting Summary Tab of school “Cirielli” which presents good components and global conditions but five local damages potentially dangerous for users.

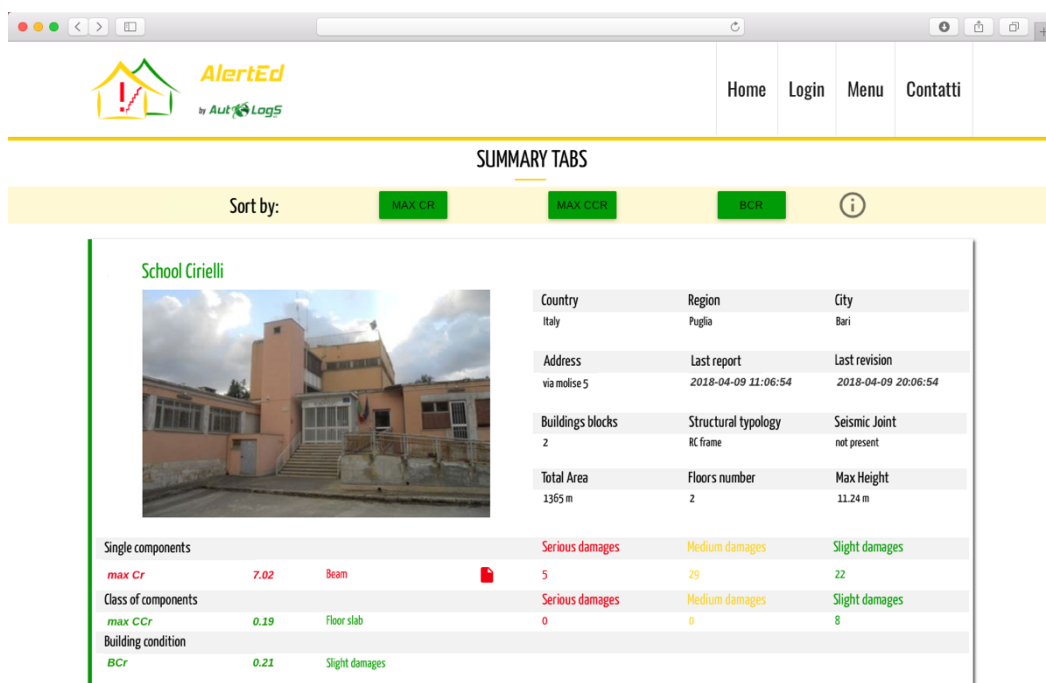


Fig. 67. - Summary Tab of school “Cirielli” in the AlertEd web-based platform.

The alerted system is able to perform all the maintenance and monitoring operations already discussed in the previous section. In addition, such a tool has the advantage of considering the effect of damages to the users safety and not only to the structure condition.

7.3 Application the DSS to obtain the index of marine exposure

In this section, the results of the *Test Site* performed in the Valencian coast are exploited to the research objective of calibrate the parameters involved in exposure to the aggressive marine environment.

This ambitious objective is achieved by employing three synergistically related techniques: i) AHP to analyze and structure the problem and define the index; ii) the building degradation analysis of DSS considering a large number of buildings; iii) an optimization procedure to calibrate the index.

The work is carried out in two levels:

- 1) The criteria, sub criteria and variables involved in the marine environment is taken into account by exploiting the widespread studies of the phenomena in the related literature. The Analytic Hierarchy Processes (AHP) is used to analyze the complex problem and define the index, following Saaty's well-known 3-step method.
- 2) The second level calibrate the index by analyse the degradation of a large number of buildings obtained in the *Test Site* in order to assess critical damage by solving an optimization problem to minimize the differences between the results of the *Index of marine exposure* (I_{me}) and the effective numerical quantification obtained by the building degradation analysis. The mathematical optimization problem exploits the results of the AHP and the building degradation analyses to obtain a calibrated index. A sensitivity analysis is also carried out to obtain robust results by considering the possible variations in the final results if the surveyed buildings had been in different sets.

7.3.1 First AHP step: Definition of criteria, subcriteria and intensity ranges

The first step of AHP, is applied to the evaluation of exposure to the marine environment, consists of the *Structure of the Problem*. The goal is to determine an index useful to quantify the *aggressive marine environment* exposure of a building. To this aim, five *criteria* i (with $i = 1, \dots, 5$) that affect the building corrosion analysed in the study by Moreno et al. (2018) are structured in a hierarchical flowchart (Fig. 68). For each *criterion* a set of three intensity ranges j (with $j = 1, \dots, 3$) is defined to characterize the exposure intensity levels of the *criterion*. The five *criteria*, *sub-criteria* and *intensity ranges* involved in the *aggressive marine environment* evaluation are shown in Fig.68 and discussed for each building as follows:

- 1) *Distance from the coast* is a determining factor in the quantity of salt particles in the air. Salinity depends on the distance from the water line and rapidly reduces with distance from this mark. Some authors (Gustafsson et al. 1996, G.R. Meira et al. 2008) found that the highest concentration of airborne chloride ions is in the first 100m. Three different *intensity ranges* are selected in Moreno et al. (2018) and included in this

problem structure: i) distance from the shore of between 0 and 50 m; ii) between 50 and 100 m and iii) distances greater than 100 m.

2) *Prevailing wind speed* also has an important influence on the salt content of the atmosphere (Rivero et al. 2017, Fitzgerald 1991). Morcillo et al. (2000) determined atmospheric salinity by analyzing the winds recorded by the weather stations on the coast of Tarragona (Spain) and found that certain directions of the prevailing wind from the sea contribute most to the inland penetration of salt particles. The average speed of a sea wind becomes critical when over 10.80 km/h due to the formation of a significant salt spray. Consequently, the three *intensity ranges* are defined as: under 9 km/h, between 9 and 10.80 km/h and over 10.80 km/h

3) *Position in relation to the water line* is important to consider the shielding effect of other buildings. In residential areas with several rows of houses, the degree of exposure is greatest on the row nearest to the beach. This difference is due to the windbreak effect of the buildings (Moreno et al. 2018). For this reason, a building can be classified in accordance with its position in the urban context into three *intensity ranges*: i) those on the sea front; ii) those on the second line; iii) and those further back.

4) *A town's type of urban growth* is also significant when analysing the influence of the marine atmosphere on its buildings. When they have shared walls, a closed unit is created with a long front and a compact volume. In other types of urban growth, the building blocks may be exposed on all sides, allowing the salt spray to circulate freely with nothing to act as a barrier. In this *criterion*, the three *intensity ranges* are classified according to the number of walls shared with other buildings, as follows: i) isolated buildings, ii) one shared wall, and iii) two shared walls.

5) *Climatic events* are connected with the moisture content in the pores (ACI 2002, Costa et al. 1999, Gustafsson et al., 1996, Meira et al. 2017), which plays a determining role in concrete resistivity (Andrade and Alonso 2001). This phenomenon has been

studied in detail by Medeiros et al. (2013), who analysed the behaviour of a structure exposed to a marine atmosphere and climatic events for 40 years. On the basis of this knowledge, the *Climatic events criterion* is divided into three *sub-criteria* k (with $k=1,\dots,3$) and their *intensity ranges* j are defined following the results of Moreno et al. (2018) and Andrade (2003). The *Climatic events sub-criteria* are the following:

- *Relative humidity* is widely studied in combination with the marine atmosphere as a cause of RC corrosion in Zaccardi et al. (2013). The relative *intensity ranges* in these studies are: under 70%, between 70%-80% and over 80%.
- *Average annual air temperature* is studied in depth together with humidity in corrosion processes by Bouteiller et al. (2012). The study found that higher temperatures are less aggressive than lower ones thanks to the reduced moisture content of the concrete. The *intensity ranges* of average annual temperatures are defined as: under 10°C, between 10°C -15°C and over 15°C.
- *Rainfall* is a decisive parameter for wetting-drying cycles (Andrade and Castillo 2003), and influences the chloride ion concentrations in the air. Morcillo et al. (2000) found high levels of salt in the air after storms, which often form salt deposits on concrete surfaces. The consequent *intensity ranges* of rainfall days are defined as: over 100 gg, between 80gg-100gg and under 80gg.

Goal	Criteria and Sub-criteria	Ranges
AGGRESSIVE MARINE ENVIRONMENT	Prevailing wind v^*_1	
		Above 10.8 km/h $w^*_{1,1}$
		Between 10.8-9 km/h $w^*_{1,2}$
		Under 9 km/h $w^*_{1,3}$
	Distance from the coast v^*_2	
		Between 0-50m $w^*_{2,1}$
		Between 50-100m $w^*_{2,2}$
		Above 100m $w^*_{2,3}$
	Position related to the water line v^*_3	
		Front line $w^*_{3,1}$
		Second line $w^*_{3,2}$
		Third or more $w^*_{3,3}$
	Urban growth types v^*_4	
		Isolated building $w^*_{4,1}$
		1 shared wall $w^*_{4,2}$
		2 or more shared walls $w^*_{4,3}$
	Climatic events v^*_5	
	Temperature $v^*_{5,1}$	Under 10° C $w^*_{5,1,1}$
		Between 10°C-15°C $w^*_{5,1,2}$
		Above 15°C $w^*_{5,1,3}$
	Rainfall $v^*_{5,2}$	Above 100gg $w^*_{5,2,1}$
		Between 80-100gg $w^*_{5,2,2}$
		Under 80gg $w^*_{5,2,3}$
	Relative Humidity $v^*_{5,3}$	Above 80 % $w^*_{5,3,1}$
		Between 70-80 % $w^*_{5,3,2}$
		Under 70 % $w^*_{5,3,3}$

Fig. 68. - Structure of the Problem: weight criteria and alternatives to determine an index able to quantify the exposure of the aggressive marine environment.

7.3.2 Second AHP step: evaluating weights

The second step in the AHP individually analyses each aspect of the *Structure of the Problem* in order to weight the parameters involved. The *criteria*, *sub-criteria* and *intensity range* weights are defined as follows:

- v^*_i is the weight associated with each i^{-th} *criterion*
- v^*_{5k} is the weight associated with the *sub-criterion* k^{-th} with $i=5$
- w^*_{ij} is the weight associated with each j^{-th} *intensity range* related to the i^{-th} *criterion*

- w^*_{5kj} is the weight associated with each j^{th} intensity range related to the k^{th} sub-criterion with $i = 5$.

This Section exploits previous studies of the phenomena involved in aggressive marine environments to obtain eight *Judgment Matrices A*: seven are used to identify the weights of the w^*_{ij} and w^*_{5kj} intensity ranges and one to identify the weight of sub-criteria v^*_{5k} . The weight calculations of the intensity ranges related to *Distance from the coast* and to the *Urban growth type* criteria are shown. *Distance from the coast* is analysed by considering the studies of different authors (Gustafsson and Franzén 1996), who found that the concentration of chloride ions in the atmosphere decreases rapidly with distance from the coast, especially in the first 100 m (Meiraet al. 2008). Following Gustafsson et al. (1996) and Meiraet al. (2008), pairwise comparisons of the alternatives are carried out performing a qualitative analysis to achieve the *Judgment Matrix A₁*. The weights are obtained by solving the eigenvector problem, as shown in Fig. 69.

A_1	a	b	u	CR	w^*_{lj}
<i>Above 10.8 km/h (a)</i>	1.0	1.5	4.0	0.0016	1.00
<i>Between 10.8-9 km/h (b)</i>	0.7	1.0	3.0		0.69
<i>Under 9 km/h (u)</i>	0.3	0.3	1.0		0.24

Fig. 69. - *Judgment Matrix A₁*, weights, and CR obtained for the intensity ranges related to “*Distance from the coast*” criterion

The resulting matrix satisfy the Consistency Ratio requirement $CR < 0.1$ and derived consistent weights w^*_{ij} , normalized between 0 and 1.

A quantitative evaluation is performed for the *urban growth type* criterion to obtain the values of matrix A_4 . This criterion considers shared walls with other buildings, so that exposure fall with the number of shared walls. For example, the value $a_{1,2}$ is obtained by comparing an isolated building with 4 free sides exposed to the marine environment with a building with 1 shared wall and 3 exposed sides. The value $a_{1,2}$ is equal to $4/3=1.3$ (rounded off to one decimal place), as shown in matrix A_4 in Fig. 70, until A_4 is obtained.

A_4	<i>i.b.</i>	<i>1 s.w.</i>	<i>2+ s.w.</i>	<i>CR</i>	w^*_{4j}
<i>Isolated building (i.b.)</i>	1.0	1.3	2.0	0.00	1.00
<i>1 shared wall (1 s.w.)</i>	0.8	1.0	1.5		0.75
<i>2 or more s.w. (2+ s.w.)</i>	0.5	0.7	1.0		0.50

Fig. 70. - *Judgment Matrix A_4 , weights, and CR obtained for the urban growth type criterion*

The weights for matrix A_4 are derived by solving the eigenvector problem by Eq. (1). The resulting matrix satisfy the Consistency Ratio requirement $CR < 0.1$ and derive consistent weights w^*_{4j} (normalized between 0 and 1), as shown in Fig. 70. After obtaining the weights of the *intensity ranges* related to each criterion, the second AHP step obtain the tabulated weights related to the *Structure of the Problem* (Table 11). Since no previous studies have been published on the criteria considered for the degree of aggressiveness of the marine environment, it is not possible to reliably evaluate their weights $v^*_{j\cdot}$. To solve this problem, the weights are calibrated by a degradation analysis and an optimization procedure.

Table 11. Tabulated weight obtained by applying AHP Step 2

Criteria/ Subcriteria	Criteria/Sub- criteria Weight	Range 1	Range 1 Weight	Range 2	Range 2 Weight	Range 3	Range 3 Weight
<i>Prevailing wind</i>	v^*_1	<i>above 10,8 km/h</i>	$w^*_{1,1}=1.0$	<i>10.8-9 km/h</i>	$w^*_{1,2}=0.69$	<i>under 9 km/h</i>	$w^*_{1,3}=0.33$
<i>Distance from the coast</i>	v^*_2	<i>0-50m</i>	$w^*_{2,1}=1.0$	<i>50-100m</i>	$w^*_{2,2}=0.69$	<i>above 100m</i>	$w^*_{2,3}=0.33$
<i>Position in relation to the water line</i>	v^*_3	<i>front line</i>	$w^*_{3,1}=1.0$	<i>second line</i>	$w^*_{3,2}=0.33$	<i>third or more</i>	$w^*_{3,3}=0.11$
<i>Urban growth types (shared walls)</i>	v^*_4	<i>isolated</i>	$w^*_{4,1}=1.0$	<i>1 shared wall</i>	$w^*_{4,2}=0.75$	<i>2+ shared walls</i>	$w^*_{4,3}=0.50$
<i>Climatic events</i>	v^*_5						
<i>Climatic events (Temperature)</i>	$v^*_{5,1} = 0.33$	<i>under 10° C</i>	$w^*_{5,1,1}=1.0$	<i>10°C-15°C</i>	$w^*_{5,1,2}=0.69$	<i>above 15°C</i>	$w^*_{5,1,3}=0.33$
<i>Climatic events (Rainfall)</i>	$v^*_{5,2} = 0.33$	<i>above 100gg</i>	$w^*_{5,2,1}=1.0$	<i>80-100gg</i>	$w^*_{5,2,2}=0.69$	<i>under 80gg</i>	$w^*_{5,2,3}=0.33$
<i>Climatic events (UR)</i>	$v^*_{5,2}=0.33$	<i>above 80 %</i>	$w^*_{5,3,1}=1.0$	<i>70-80 %</i>	$w^*_{5,3,2}=0.69$	<i>under 70 %</i>	$w^*_{5,3,3}=0.33$

7.3.3 Third AHP step: definition of marine exposure index

After weighting, the marine exposure index (I_{me}) can be defined. This operation coincides with the third step of the summary of priority. The formula is obtained by multiplying each criteria weight by the *intensity range* weight and adding the results, as in the classical AHP procedure (Sangiorgio et al. 2017b, Saaty 1987):

$$I_{me} = v^*_1 * w^*_{1j} + v^*_2 * w^*_{2j} + v^*_3 * w^*_{3j} + v^*_4 * w^*_{4j} + v^*_5 (v^*_{5,1} * w^*_{5,1j} + v^*_{5,2} * w^*_{5,2j} + v^*_{5,3} * w^*_{5,3j}) \quad (28)$$

The w_{ij} and w_{5ij} weights are obtained in the second AHP step, as can be seen in Table 11. v^*_i is the weight associated with each i^{th} criterion and represents the variables in Eq. (28) and in the subsequent optimization problem.

7.3.4 Calibration by an optimization procedure and sensitivity analysis using BCr

In order to obtain the weights v^* and calibrate the index of marine exposure defined in Eq. (4), we consider the $K=131$ surveyed buildings of the *Test Site*, in *El Perellonet*, *Puebla de Farnals* and *El Puig*. The index of marine exposure I_{me}^{Bu} associated with building $Bu=1, \dots, K$ is written in function of the column vector of weights $v^* = [v^*_1, v^*_2, v^*_3, v^*_4, v^*_5]^T$ as follows:

$$I_{me}^{Bu}(v^*) = v^*_1 * w^*_{1j} + v^*_2 * w^*_{2j} + v^*_3 * w^*_{3j} + v^*_4 * w^*_{4j} + v^*_5 (v^*_{5,1} * w^*_{5,1j} + v^*_{5,2} * w^*_{5,2j} + v^*_{5,3} * w^*_{5,3j}) \quad (29)$$

We now define function $F(v^*)$, which evaluates the difference between the values of I_{me}^{Bu} and BCr^{Bu} calculated for each surveyed building $Bu=1, \dots, K$:

$$F(v^*) = \sum_{Bu=1}^K |I_{me}^{Bu}(v^*) - BCr^{Bu}| \quad (30)$$

It is widely accepted in the related literature that damage to buildings close to the coast is principally due to the aggressive marine environment and that the most exposed buildings are typically the most seriously damaged. To calibrate vector $\mathbf{v}$, we therefore assumed that the index of marine exposure I_{me}^{Bu} should be as close as possible to the index of effective damage BCr^{Bu} for the studied buildings.

$F(\mathbf{v})$ represents the sum of the differences between the index of marine exposure and the effective degradation of the buildings. Consequently, we set $F(\mathbf{v})$ as the objective function to be minimized by satisfying a set of constraints on vector $\mathbf{v}$:

$\Gamma(\mathbf{v}^*)$:

$$\sum_{i=1}^5 v^*_i = 1 \quad (31a)$$

$$v^*_i \leq 0.6 \text{ for } i=1, \dots, 5 \quad (31b)$$

$$v^*_i \geq 0.05 \text{ for } i=1, \dots, 5 \quad (31c)$$

Constraint Eq. (31a) is a normalization derived from the formulation of the classical index of the AHP procedure, and constraints Eq. (31b, 31c) are set to avoid overestimation and null values of the weights, respectively.

Now, in order to calculate vector $\mathbf{v}$, the following Mathematical Programming (MP) problem is formulated:

$$\min F(\mathbf{v}^*) \quad (32a)$$

$$\text{subject to } \Gamma(\mathbf{v}^*). \quad (32b)$$

A sensitivity analysis is also performed to obtain a robust result. The evaluation took into account how the final results would have changed, had a different set of buildings been surveyed. For this, 1000 different optimizations are solved and in each formulation

we removed a random number $m < 0.3 K$ of buildings selected at random and with uniform probability from the complete set.

As an example, Fig. 71 shows the scheme of the random removal of buildings to obtain a new set to be used in the MP problem solution. The 1000 optimization problems provide seven different solutions $v^{Opt,n}$ with $n=1, \dots, 7$ and l^n represents the number of times the n^{th} solution is found.

The chosen value of weights v^* is obtained by a weighted average as follows:

$$v^* = \frac{\sum_{n=1}^7 v^{Opt,n} * l^n}{\sum_{n=1}^7 l^n}. \quad (33)$$

Optimization 1	Optimization 2	Optimization 3	Optimization 1000
Building 1	Building 1	Building 1	Building 1
Building 2	Building 2	Building 2	Building 2
Building 3	Building 3	Building 3	Building 3
Building 4	Building 4	Building 4	Building 4
Building 5	Building 5	Building 5	Building 5
Building 6	Building 6	Building 6	Building 6
Building 7	Building 7	Building 7	Building 7
Building 8	Building 8	Building 8	Building 8
Building 9	Building 9	Building 9	Building 9
...	...	...	...
Building 131	Building 131	Building 131	Building 131

Fig. 71. - An example of random removal of buildings for 1000 different optimizations

The sensitivity analysis parameters given in Fig.72 show that the optimization problem found robust solutions, since the maximum value of a standard deviation of 0.073 is obtained for the *position related to the water line* criterion, while the average and median values of each component of v^* effectively coincide. The result of the analysis suggests that the most important criteria for exposure to an aggressive marine environment are: *distance from the coast*, with a weight of $v_2^*=0.496$ and *position related to the water line*, with a weight of $v_3^*=0.341$ (Fig. 72).

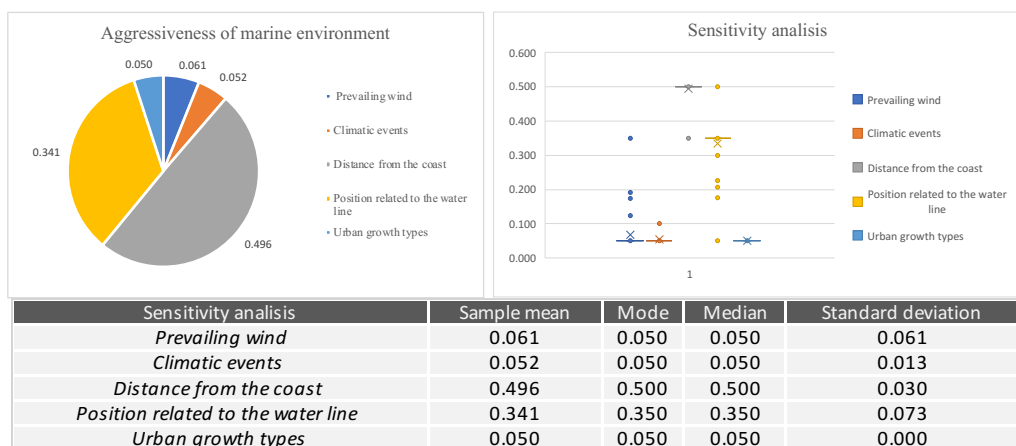


Fig. 72. - Result of the calibration and data produced by the sensitivity analysis

7.3.5 Example of I_{me} application

The calibration obtained by the DSS methodology is used to evaluate a marine exposure index.

In order to show a simple application, the index of marine exposure I_{me} is calculated for *Building 51* in *El Perellonet*. The building's marine exposure data are shown in Fig. 73. Using the tabulated weights computed by the AHP (Table 11) and the weights v^* obtained by the calibrations of the DSS methodology, it is possible to obtain the index $I_{me}(v^*)$:

$$I_{me}(v^*) = 0.24 * 0.061 + 0.24 * 0.496 + 1.0 * 0.341 + 1.0 * 0.05 + 1.0 * 0.052 = 0.58$$

This value can be analyzed together with the effective damage normalized to 1 surveyed in the building ($BCr=0.83$). It can be deduced that this building has a medium exposure to the marine environment, although serious damage is also found due to poor maintenance and poor design.

El Perellonet	Prevailing wind			Climatic events		
Edificio 51	Under 9 Km/h	9 - 10.8 Km/h	Above 10.8 Km/h	Temperature (C)	Rainfall (gg)	UR (%)
	6			18.3	45	66
	Distance from the water line			Year of construction of building		
	First line	Second line	Thirtd line	1968-1985	1985-1998	1998-2007
	X			X		
	Distance from the coast			Urban growth types (% building)		
	0-50 m	50-100 m	above 100 m	isolated	1 shared walls	2+ shared walls
	48			X		

Fig. 73. - Environmental data of Building 51 in El Perellonet

CONCLUSIONS

This thesis proposes an innovative user-reporting methodology integrated into a DSS prototype for the R.C. building degradation analysis at regional scale. The project involved a combination of interdisciplinary skills, including: structural engineering, forensic engineering, building degradation analysis, statistics, optimization and multi-criteria analysis.

The novelty of the presented work is fourfold: i) the *DSS methodology* supported by modern Internet of Things tools (smart devices) and Information Technologies; ii) the new *Optimized AHP methodology* to derive weights; iii) a *calibration procedure* based on the Tuutti model to consider the damage evolution of reinforcements' corrosion; iv) a *Test Site* involving 131 building on the Valencian coasts to assess the DSS.

Each one of these aspects has been studied in detail and the main findings are discussed below:

- i) The specified *DSS methodology* is particularly effective in contexts characterized by limited information about registry data and technical specifications, and where scheduled maintenance is not a common practice. The methodological phases of *Data acquisition*, *Data processing* and *Diagnostic* defined to perform the damage assessment of buildings has been described and mathematically specified. The data acquisition phase is performed by *Registry Sheets* and a smart device application (*APP*) for user reporting. The second phase, *Data processing*, is based on a suitable classification of pathologies. The third *Diagnostics Phase* is performed through a semeiotic approach. To this aim, a set of KPIs is defined and classified.
- ii) The new *Optimized AHP methodology* to derive weights is one of the key points of the research. This new strategy allows the application of the AHP methodology even if the problem is complex, a large number of criteria and comparisons are necessary, and the consistency is not easy to obtain. This work focuses on the drawback of the standard AHP, determined by the limited capacity of the human mind to assign coherent judgments when the number of simultaneous comparisons is large. Moreover, from a

mathematical point of view, the reliability and coherence of the resulting weights evaluated by the *Judgment Matrix* are critical issues when the number of alternatives increases and the standard AHP is applied. The proposed methodology overcomes the standard AHP drawbacks by revising the AHP weights evaluation procedure. First, the exact judgment assignments are replaced by judgment ranges. Second, the entries of the *Judgment Matrix* are provided by an MP formulation that minimizes the inconsistency of the matrix subject to the constraints imposed on the weights. The main benefits of the resulting approach are the simplification of the decision-maker operations in the case of a large number of alternatives, and the determination of the *Judgment Matrix* that is obtained by optimizing the congruence and respecting the constraints imposed by the decision maker. In contrast, the O-AHP is able to generate a *Judgment Matrix* that exhibits the minimum value of inconsistency, regardless of whether the decision maker omits some judgment ranges. To validate the O-AHP methodology, a benchmark test proposed in the related literature is used: the results show the effectiveness of the O-AHP also in the case of a large number of criteria. Therefore, the O-AHP method opens up new possibilities to AHP application in the field of construction, in which a large number of alternatives and criteria has to be evaluated.

iii) The *Calibration procedure* is performed through a comparison with the method GDE-UnB extensively and fruitfully applied in South America for the degradation evaluation of reinforced concrete buildings. The calibration is set by exploiting four case studies to obtain most reliable KPIs in the proposed method. In particular, this study has provided the following results: 1) it is shown how the calibration with the Tuutti model improves the accuracy of the KPIs and makes the two comparative methodologies more similar but worsens the robustness; 2) a calibration of the KPIs for detecting building structural degradation is performed by the Tuutti model, achieving an optimal compromise between accuracy and robustness; 3) the proposed method and the GDE-UnB are applied to 4 different R.C. structures: the results show that the trend of the building damage evaluation of the two methods is similar and that the DSS KPIs are more robust than GDE-UnB ones.

iv) A *Test Site* is performed in order to carry out a first application of the proposed DSS. The described DSS approach has been applied to two 131 building on the Valencian coasts exposed to an aggressive marine environment. The results obtained for the case studies have shown that the Diagnostics Sheets and *Matrices of Damage* allow an effective qualification of the local and global conditions of the buildings. In addition, the KPIs allow the identification of some alert situations, which are potentially dangerous for human or building safety, and the prioritization of the interventions.

The resulting DSS performs an automatic computation of the KPIs and allows working on a regional scale with limited resources. This tool can be used by architects, engineers, and interested stakeholders and researchers to improve management and maintenance, prioritize interventions or carry out complex degradation analyses on a large scale. It is worth noting that that the proposed methodology is applied, in this work, to the reinforced concrete buildings. However, the same procedure can be extended to masonry buildings by studying in deep the related pathologies in order to set up an instrument effective for every main building typology. In addition, the methodology can be easily applied in other regions or at a different scale, considering specific local problems, by applying the following modifications: i) update the structure of the problem on the basis of the specific pathologies present in the new region by redefine goals, criteria and alternatives; ii) apply the O-AHP procedure to obtain the updated Weight Evaluation; iii) individuate in the new context the building users that can reports the building pathologies by the APP.

In order to show the applicability of the DSS to different problems, the described DSS approach has been applied to two school buildings in the municipality of Bari, Italy. The results obtained for the case studies have shown that the Diagnostics Sheets and *Matrix of Damage* allow an effective qualification of the local and global conditions of the buildings. In addition, the KPIs allow the identification of some alert situations, which are potentially dangerous for human or building safety, and the prioritization of the interventions.

Finally, in order to exhibit the DSS potentiality from a research point of view, the results of the large scale degradation analyses performed in the *Test Site* are used to calibrate an index devoted to quantifying the exposure of RC building structures to a marine environment. The obtained I_{me} index could be a useful tool to measure a building's exposure to an aggressive marine environment in any phase of the building process, from the project phase to the building maintenance and management phases. It could also be used to evaluate the outdoor environment in predicting service life and as a support for improved RC corrosion measures. This synthetic index can be applied on an urban scale for urban planning and coastal urban developments.

Future research will study a new method based on the developed DSS approach to evaluate the residual life of components and obtain a preliminary vulnerability assessment of the building. In order to perform such evaluation, new IoT techniques will be implemented in the buildings to be investigated. A suitable set of networked RFID (Radio Frequency IDentification) or devices communicating by Bluetooth Smart will be positioned in each room for the identification of each element in the building plan

In addition, the applicability of the system will be extended for the masonry buildings, which represent a particularly vulnerable typology. The experiences progressively acquired during post-earthquakes, floods, and hurricanes surveys and the consequent research studies have revealed that recurrent damage patterns and failure mechanisms can be identified, leading to the idea that it is possible to separately investigate the different architectural “macro-elements” of the building. The damage assessment and subsequently the seismic vulnerability of heritage buildings at the regional scale can be addressed by the DSS approach by developing of specific multi-level procedures based on the inventory and classification of typological, constructive features, vulnerability parameters, potential or existing damage.

The QDP will be set to evaluates a vulnerability index by using the macro-element approach. Furthermore, the AHP can be used to improve the interpretations of the

obtained measures and calibrate the relative importance of the kinematic and static criteria and automatically assign the weight to each criterion and alternative.

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ATTACHMENTS 1

Validation benchmark test matrix A^{Opt}_{test}										
$CI=0.0019$	A	B	C	D	E	w^{Opt}_{test}	rv	$Pe(w^{Opt}_{test})$	w_{test}	$Pe(w_{test})$
$RI=1.44$										
$CR=0.0013$										
A	1.00	9.00	2.50	3.45	6.00	0.498	0.47	4.8%	0.488	4.7%
B	0.11	1.00	0.20	0.33	0.59	0.049	0.05		0.049	
C	0.40	5.00	1.00	1.60	2.71	0.225	0.24		0.233	
D	0.29	3.00	0.63	1.00	1.74	0.144	0.14		0.148	
E	0.17	1.68	0.37	0.57	1.00	0.083	0.09		0.082	

Validation benchmark test JR				
i-th element	K^L_{ij}	a_{ij}	K^U_{ij}	j-th element
A	9.0	$\leq a_{1,2} \leq$	9.0	B
A	2.5	$\leq a_{1,3} \leq$	3.0	C
A	2.0	$\leq a_{1,4} \leq$	6.0	D
A	4.0	$\leq a_{1,5} \leq$	8.0	E
B	1/6	$\leq a_{2,3} \leq$	1/5	C
B	1/4	$\leq a_{2,4} \leq$	1/3	D
B	1/2	$\leq a_{2,5} \leq$	1/1.5	E
C	1.6	$\leq a_{3,4} \leq$	1.8	D
C	1.0	$\leq a_{3,5} \leq$	3.0	E
D	1.0	$\leq a_{4,5} \leq$	2.0	E

Validation benchmark test 1.2 matrix $A^{Opt}_{test,1.2}$											
$CI=$	0.0002	A	B	C	D	E	$w^{Opt}_{test,1.2}$	rv	$Pe(w^{Opt}_{test,1.2})$	w_{test}	$Pe(w_{test})$
$RI=$	1.44										
$CR=$	0.0001										
	A	1.00	9.00	1.90	3.00	5.50	0.498	0.47	4.4%	0.486	4.7%
	B	0.11	1.00	0.20	0.32	0.56	0.049	0.05		0.049	
	C	0.53	4.92	1.00	1.60	2.82	0.225	0.24		0.233	
	D	0.33	3.09	0.63	1.00	1.77	0.144	0.14		0.148	
	E	0.18	1.80	0.35	0.56	1.00	0.083	0.09		0.082	

Validation benchmark test 1.2 JR				
i-th element	K^L_{ij}	a_{ij}	K^U_{ij}	j-th element
A	9.0	$\leq a_{1,2} \leq$	9.0	B
A	1.9	$\leq a_{1,3} \leq$	2.0	C
A	3.0	$\leq a_{1,4} \leq$	3.8	D
A	5.5	$\leq a_{1,5} \leq$	6.0	E
B	1/5,5	$\leq a_{2,3} \leq$	1/4,8	C
B	1/4	$\leq a_{2,4} \leq$	1/3	D
B	1/2	$\leq a_{2,5} \leq$	1/1.8	E
C	1.6	$\leq a_{3,4} \leq$	1.8	D
C	2.5	$\leq a_{3,5} \leq$	3.0	E
D	1.2	$\leq a_{4,5} \leq$	2.0	E

Validation benchmark test 1.3 matrix $A^{Opt}_{test,1.3}$											
$CI=$	0.0002	A	B	C	D	E	$w^{Opt}_{test,1.3}$	rv	$Pe(w^{Opt}_{test,1.3})$	w_{test}	$Pe(w_{test})$
$RI=$	1.44										
$CR=$	0.0001										
	A	1.00	9.00	1.80	3.00	5.50	0.458	0.47	4.7%	0.486	4.7%
	B	0.11	1.00	0.19	0.32	0.56	0.049	0.05		0.049	
	C	0.56	5.16	1.00	1.67	2.96	0.254	0.24		0.233	
	D	0.33	3.10	0.60	1.00	1.78	0.153	0.14		0.148	
	E	0.18	1.80	0.34	0.56	1.00	0.086	0.09		0.082	

Validation benchmark test 1.3 JR					
i-th element	K^L_{ij}		a_{ij}	K^U_{ij}	j-th element
A	9.0	$\leq$	$a_{1,2}$	$\leq$ 9.0	B
A	1.8	$\leq$	$a_{1,3}$	$\leq$ 2.0	C
A	3.0	$\leq$	$a_{1,4}$	$\leq$ 3.5	D
A	5.5	$\leq$	$a_{1,5}$	$\leq$ 6.0	E
B	1/5,2	$\leq$	$a_{2,3}$	$\leq$ 1/5,0	C
B	1/4	$\leq$	$a_{2,4}$	$\leq$ 1/3	D
B	1/2	$\leq$	$a_{2,5}$	$\leq$ 1/1,8	E
C	1.5	$\leq$	$a_{3,4}$	$\leq$ 1.8	D
C	2.5	$\leq$	$a_{3,5}$	$\leq$ 3.0	E
D	1.5	$\leq$	$a_{4,5}$	$\leq$ 2.0	E

Validation benchmark test 1.4 matrix $A^{Opt}_{test,1.4}$											
$CI=$	0.0001	A	B	C	D	E	$w^{Opt}_{test,1.4}$	rv	$Pe(w^{Opt}_{test,1.4})$	w_{test}	$Pe(w_{test})$
$RI=$	1.44										
$CR=$	0.0001										
	A	1.00	9.00	1.80	3.00	5.50	0.479	0.47	3.4%	0.486	4.7%
	B	0.11	1.00	0.19	0.32	0.56	0.051	0.05		0.049	
	C	0.56	5.16	1.00	1.67	2.96	0.229	0.24		0.233	
	D	0.33	3.10	0.60	1.00	1.78	0.151	0.14		0.148	
	E	0.18	1.80	0.34	0.56	1.00	0.089	0.09		0.082	

Validation benchmark test 1.4 JR					
i-th element	K^L_{ij}		a_{ij}	K^U_{ij}	j-th element
A	8.5	$\leq$	$a_{1,2}$	$\leq$ 9.0	B
A	1.9	$\leq$	$a_{1,3}$	$\leq$ 2.1	C
A	3.2	$\leq$	$a_{1,4}$	$\leq$ 3.5	D
A	5.5	$\leq$	$a_{1,5}$	$\leq$ 6.0	E
B	1/5,2	$\leq$	$a_{2,3}$	$\leq$ 1/4,5	C
B	1/4	$\leq$	$a_{2,4}$	$\leq$ 1/3	D
B	1/2	$\leq$	$a_{2,5}$	$\leq$ 1/1,8	E
C	1.5	$\leq$	$a_{3,4}$	$\leq$ 2.0	D
C	2.5	$\leq$	$a_{3,5}$	$\leq$ 2.8	E
D	1.5	$\leq$	$a_{4,5}$	$\leq$ 2.0	E

Validation benchmark test 1.5 matrix $A^{Opt}_{test,1.3}$											
$C/=$	0.0001	A	B	C	D	E	$w^{Opt}_{test,1.5}$	rv	$Pe(w^{Opt}_{test,1.5})$	w_{test}	$Pe(w_{test})$
$R/=$	1.44										
$CR=$	0.0001										
	A	1.00	9.00	1.80	3.00	5.50	0.474	0.47	3.9%	0.486	4.7%
	B	0.11	1.00	0.19	0.32	0.56	0.050	0.05		0.049	
	C	0.56	5.16	1.00	1.67	2.96	0.245	0.24		0.233	
	D	0.33	3.10	0.60	1.00	1.78	0.150	0.14		0.148	
	E	0.18	1.80	0.34	0.56	1.00	0.082	0.09		0.082	

Validation benchmark test 1.5 JR					
i-th element	K^L_{ij}		a_{ij}	K^U_{ij}	j-th eement
A	8.5	≤	$a_{1,2}$	≤ 9.0	B
A	1.9	≤	$a_{1,3}$	≤ 2.1	C
A	3.2	≤	$a_{1,4}$	≤ 3.5	D
A	5.5	≤	$a_{1,5}$	≤ 6.0	E
B	1/5,2	≤	$a_{2,3}$	≤ 1/4,5	C
B	1/4	≤	$a_{2,4}$	≤ 1/3	D
B	1/2	≤	$a_{2,5}$	≤ 1/1,8	E
C	1.5	≤	$a_{3,4}$	≤ 2.0	D
C	2.5	≤	$a_{3,5}$	≤ 2.8	E
D	1.5	≤	$a_{4,5}$	≤ 2.0	E

Validation benchmark test 2 matrix $A^{Opt}_{test,2}$																
$C/ = 0.0006$	G	A	I	L	C	N	M	D	F	E	H	B	$w^{Opt}_{test,2}$	rv	$Pe(w^{Opt}_{test,2})$	
$R/ = 1.44$																
$CR = 0.0004$																
G	1.00	1.27	1.24	2.35	2.49	3.22	3.64	4.00	5.71	6.79	7.69	9.00	0.206	0.208	2.40%	
A	0.79	1.00	1.00	1.91	2.00	2.51	3.14	3.32	3.91	5.38	6.58	8.45	0.167	0.167		
I	0.80	1.00	1.00	1.84	2.00	2.48	2.91	3.36	4.41	5.10	6.87	7.64	0.165	0.160		
L	0.43	0.52	0.54	1.00	1.09	1.33	1.50	1.76	2.31	2.76	3.63	4.58	0.089	0.089		
C	0.40	0.50	0.50	0.92	1.00	1.28	1.41	1.68	2.26	2.64	3.44	4.30	0.084	0.082		
N	0.31	0.40	0.40	0.75	0.78	1.00	1.24	1.32	1.75	2.00	2.72	3.38	0.067	0.066		
M	0.27	0.32	0.34	0.67	0.71	0.80	1.00	1.13	1.46	1.76	2.30	2.71	0.056	0.056		
D	0.25	0.30	0.30	0.57	0.60	0.76	0.88	1.00	1.34	1.61	2.00	2.50	0.050	0.053		
F	0.18	0.26	0.23	0.43	0.44	0.57	0.68	0.75	1.00	1.22	1.58	1.85	0.038	0.039		
E	0.15	0.19	0.20	0.36	0.38	0.50	0.57	0.62	0.82	1.00	1.29	1.59	0.032	0.033		
H	0.13	0.15	0.15	0.28	0.29	0.37	0.43	0.50	0.63	0.77	1.00	1.23	0.025	0.026		
B	0.11	0.12	0.13	0.22	0.23	0.30	0.37	0.40	0.54	0.63	0.82	1.00	0.020	0.021		

Validation benchmark test2 JR									
i-th element	K^i_{ij}	a_{ij}	K^j_{ij}	j-th element	i-th element	K^i_{ij}	a_{ij}	K^j_{ij}	j-th element
G	1.2 ≤	$a_{1,2}$ ≤	1.5	A	L	1.5 ≤	$a_{4,8}$ ≤	2.0	D
G	1.0 ≤	$a_{1,3}$ ≤	2.0	I	L	2.0 ≤	$a_{4,9}$ ≤	4.0	F
G	2.0 ≤	$a_{1,4}$ ≤	3.0	L	L	2.0 ≤	$a_{4,10}$ ≤	3.0	E
G	2.0 ≤	$a_{1,5}$ ≤	3.0	C	L	3.0 ≤	$a_{4,11}$ ≤	5.0	H
G	3.0 ≤	$a_{1,6}$ ≤	4.0	N	L	4.0 ≤	$a_{4,12}$ ≤	6.0	B
G	3.0 ≤	$a_{1,7}$ ≤	4.0	M	C	1.0 ≤	$a_{5,6}$ ≤	1.5	N
G	4.0 ≤	$a_{1,8}$ ≤	4.0	D	C	1.0 ≤	$a_{5,7}$ ≤	1.5	M
G	5.0 ≤	$a_{1,9}$ ≤	7.0	F	C	1.5 ≤	$a_{5,8}$ ≤	2.0	D
G	6.0 ≤	$a_{1,10}$ ≤	8.0	E	C	2.0 ≤	$a_{5,9}$ ≤	3.0	F
G	7.0 ≤	$a_{1,11}$ ≤	8.0	H	C	2.0 ≤	$a_{5,10}$ ≤	3.0	E
G	9.0 ≤	$a_{1,12}$ ≤	9.0	B	C	3.0 ≤	$a_{5,11}$ ≤	4.0	H
A	1.0 ≤	$a_{2,3}$ ≤	1.0	I	N	4.0 ≤	$a_{5,12}$ ≤	6.0	B
A	1.5 ≤	$a_{2,4}$ ≤	3.0	L	N	1.2 ≤	$a_{6,7}$ ≤	1.5	M
A	2.0 ≤	$a_{2,5}$ ≤	2.0	C	N	1.0 ≤	$a_{6,8}$ ≤	1.5	D
A	2.0 ≤	$a_{2,6}$ ≤	3.0	N	N	1.5 ≤	$a_{6,9}$ ≤	2.0	F
A	3.0 ≤	$a_{2,7}$ ≤	4.0	M	N	2.0 ≤	$a_{6,10}$ ≤	2.0	E
A	3.0 ≤	$a_{2,8}$ ≤	5.0	D	N	2.5 ≤	$a_{6,11}$ ≤	3.0	H
A	2.0 ≤	$a_{2,9}$ ≤	4.0	F	N	3.0 ≤	$a_{6,12}$ ≤	4.0	B
A	5.0 ≤	$a_{2,10}$ ≤	6.0	E	M	1.0 ≤	$a_{7,8}$ ≤	1.5	D
A	6.0 ≤	$a_{2,11}$ ≤	7.0	H	M	1.0 ≤	$a_{7,9}$ ≤	2.0	F
A	8.0 ≤	$a_{2,12}$ ≤	9.0	B	M	1.5 ≤	$a_{7,10}$ ≤	2.0	E
I	1.5 ≤	$a_{3,4}$ ≤	2.0	L	M	1.5 ≤	$a_{7,11}$ ≤	3.0	H
I	2.0 ≤	$a_{3,5}$ ≤	2.0	C	M	1.0 ≤	$a_{7,12}$ ≤	3.0	B
I	2.0 ≤	$a_{3,6}$ ≤	3.0	N	D	1.2 ≤	$a_{8,9}$ ≤	1.5	F
I	2.0 ≤	$a_{3,7}$ ≤	4.0	M	D	1.5 ≤	$a_{8,10}$ ≤	2.0	E
I	3.0 ≤	$a_{3,8}$ ≤	4.0	D	D	2.0 ≤	$a_{8,11}$ ≤	2.0	H
I	4.0 ≤	$a_{3,9}$ ≤	5.0	F	D	2.0 ≤	$a_{8,12}$ ≤	3.0	B
I	4.0 ≤	$a_{3,10}$ ≤	6.0	E	F	1.0 ≤	$a_{9,10}$ ≤	1.5	E
I	6.0 ≤	$a_{3,11}$ ≤	8.0	H	F	1.5 ≤	$a_{9,11}$ ≤	2.0	H
I	7.0 ≤	$a_{3,12}$ ≤	8.0	B	F	1.5 ≤	$a_{9,12}$ ≤	2.0	B
L	1.0 ≤	$a_{4,5}$ ≤	1.5	C	E	1.0 ≤	$a_{10,11}$ ≤	1.5	H
L	1.0 ≤	$a_{4,6}$ ≤	1.5	N	E	1.5 ≤	$a_{10,12}$ ≤	2.0	B
L	1.5 ≤	$a_{4,7}$ ≤	1.5	M	H	1.0 ≤	$a_{11,12}$ ≤	1.5	B

G	CIRCLE 2
A	Circle
I	SQUARE 2
L	DIAMOND 2
C	Square
N	ISOSCELES TRAPEZOID 2
M	RECTANGLE 2
D	Diamond
F	Isosceles trapezoid
E	Rectangle
H	TRIANGLE 2
B	Triangle

Validation benchmark test 2 matrix $A^{Opt}_{test,2}$ (Weight obtained by remove the uncertain judgment ranges)																
$CI=$	0.011	G	A	I	L	C	N	M	D	F	E	H	B	$w^{Opt}_{test,2}$	rv	$Pe(w^{Opt}_{test,2})$
$RI=$	1.44															
$CR=$	0.007															
	G	1.00	1.27	1.24	2.35	2.49	3.22	3.64	4.00	5.71	6.79	7.69	9.00	0.204	0.208	7.00%
	A	0.79	1.00	1.00	1.91	2.00	2.51	3.14	3.32	3.91	5.38	6.58	8.45	0.170	0.167	
	I	0.80	1.00	1.00	1.84	2.00	2.48	2.91	3.36	4.41	5.10	6.87	7.64	0.164	0.160	
	L	0.43	0.52	0.54	1.00	1.09	1.33	1.50	1.76	2.31	2.76	3.63	4.58	0.097	0.089	
	C	0.40	0.50	0.50	0.92	1.00	1.28	1.41	1.68	2.26	2.64	3.44	4.30	0.087	0.082	
	N	0.31	0.40	0.40	0.75	0.78	1.00	1.24	1.32	1.75	2.00	2.72	3.38	0.069	0.066	
	M	0.27	0.32	0.34	0.67	0.71	0.80	1.00	1.13	1.46	1.76	2.30	2.71	0.057	0.056	
	D	0.25	0.30	0.30	0.57	0.60	0.76	0.88	1.00	1.34	1.61	2.00	2.50	0.048	0.053	
	F	0.18	0.26	0.23	0.43	0.44	0.57	0.68	0.75	1.00	1.22	1.58	1.85	0.035	0.039	
	E	0.15	0.19	0.20	0.36	0.38	0.50	0.57	0.62	0.82	1.00	1.29	1.59	0.028	0.033	
	H	0.13	0.15	0.15	0.28	0.29	0.37	0.43	0.50	0.63	0.77	1.00	1.23	0.023	0.026	
	B	0.11	0.12	0.13	0.22	0.23	0.30	0.37	0.40	0.54	0.63	0.82	1.00	0.019	0.021	

Validation benchmark test 2 JR (remove the uncertain judgment ranges)									
i-th element	K^L_{ij}	a_{ij}	K^U_{ij}	j-th element	i-th element	K^L_{ij}	a_{ij}	K^U_{ij}	j-th element
G	1.2	$\leq a_{1,2}$	≤ 1.5	A	L	1.0	$\leq a_{4,8}$	≤ 9.0	D
G	1.0	$\leq a_{1,3}$	≤ 2.0	I	L	1.0	$\leq a_{4,9}$	≤ 9.0	F
G	2.0	$\leq a_{1,4}$	≤ 3.0	L	L	2.0	$\leq a_{4,10}$	≤ 3.0	E
G	2.0	$\leq a_{1,5}$	≤ 3.0	C	L	1.0	$\leq a_{4,11}$	≤ 9.0	H
G	3.0	$\leq a_{1,6}$	≤ 4.0	N	L	1.0	$\leq a_{4,12}$	≤ 9.0	B
G	1.0	$\leq a_{1,7}$	≤ 9.0	M	C	1.0	$\leq a_{5,6}$	≤ 1.5	N
G	1.0	$\leq a_{1,8}$	≤ 9.0	D	C	1.0	$\leq a_{5,7}$	≤ 1.5	M
G	1.0	$\leq a_{1,9}$	≤ 9.0	F	C	1.5	$\leq a_{5,8}$	≤ 2.0	D
G	1.0	$\leq a_{1,10}$	≤ 9.0	E	C	1.0	$\leq a_{5,9}$	≤ 9.0	F
G	1.0	$\leq a_{1,11}$	≤ 9.0	H	C	1.0	$\leq a_{5,10}$	≤ 9.0	E
G	9.0	$\leq a_{1,12}$	≤ 9.0	B	C	1.0	$\leq a_{5,11}$	≤ 9.0	H
A	1.0	$\leq a_{2,3}$	≤ 1.0	I	N	1.0	$\leq a_{5,12}$	≤ 9.0	B
A	1.5	$\leq a_{2,4}$	≤ 3.0	L	N	1.2	$\leq a_{6,7}$	≤ 1.5	M
A	2.0	$\leq a_{2,5}$	≤ 2.0	C	N	1.0	$\leq a_{6,8}$	≤ 1.5	D
A	1.0	$\leq a_{2,6}$	≤ 9.0	N	N	1.5	$\leq a_{6,9}$	≤ 2.0	F
A	1.0	$\leq a_{2,7}$	≤ 9.0	M	N	1.0	$\leq a_{6,10}$	≤ 9.0	E
A	1.0	$\leq a_{2,8}$	≤ 9.0	D	N	1.0	$\leq a_{6,11}$	≤ 9.0	H
A	1.0	$\leq a_{2,9}$	≤ 9.0	F	N	1.0	$\leq a_{6,12}$	≤ 9.0	B
A	1.0	$\leq a_{2,10}$	≤ 9.0	E	M	1.0	$\leq a_{7,8}$	≤ 1.5	D
A	6.0	$\leq a_{2,11}$	≤ 7.0	H	M	1.0	$\leq a_{7,9}$	≤ 2.0	F
A	8.0	$\leq a_{2,12}$	≤ 9.0	B	M	1.0	$\leq a_{7,10}$	≤ 9.0	E
I	1.5	$\leq a_{3,4}$	≤ 2.0	L	M	1.0	$\leq a_{7,11}$	≤ 9.0	H
I	2.0	$\leq a_{3,5}$	≤ 2.0	C	M	1.0	$\leq a_{7,12}$	≤ 9.0	B
I	2.0	$\leq a_{3,6}$	≤ 3.0	N	D	1.2	$\leq a_{8,9}$	≤ 1.5	F
I	2.0	$\leq a_{3,7}$	≤ 4.0	M	D	1.0	$\leq a_{8,10}$	≤ 9.0	E
I	3.0	$\leq a_{3,8}$	≤ 4.0	D	D	2.0	$\leq a_{8,11}$	≤ 2.0	H
I	1.0	$\leq a_{3,9}$	≤ 9.0	F	D	1.0	$\leq a_{8,12}$	≤ 9.0	B
I	1.0	$\leq a_{3,10}$	≤ 9.0	E	F	1.0	$\leq a_{9,10}$	≤ 1.5	E
I	1.0	$\leq a_{3,11}$	≤ 9.0	H	F	1.5	$\leq a_{9,11}$	≤ 2.0	H
I	7.0	$\leq a_{3,12}$	≤ 8.0	B	F	1.5	$\leq a_{9,12}$	≤ 2.0	B
L	1.0	$\leq a_{4,5}$	≤ 1.5	C	E	1.0	$\leq a_{10,11}$	≤ 1.5	H
L	1.0	$\leq a_{4,6}$	≤ 1.5	N	E	1.5	$\leq a_{10,12}$	≤ 2.0	B
L	1.0	$\leq a_{4,7}$	≤ 9.0	M	H	1.0	$\leq a_{11,12}$	≤ 1.5	B

Validation benchmark test 2.2 matrix $A^{Opt}_{test,2,2}$																
$CI=$	0.011	G	A	I	L	C	N	M	D	F	E	H	B	$w^{Opt}_{test,2,2}$	rv	$Pe(w^{Opt}_{test,2})$
$RI=$	1.44															
$CR=$	0.007															
G	1.0	1.2	1.3	2.2	2.2	2.6	3.4	3.8	5.2	6.0	7.8	8.8	0.200	0.208		
A	0.8	1.0	1.2	1.7	1.7	2.8	3.0	3.1	4.5	4.5	5.2	5.5	0.162	0.167		
I	0.8	0.8	1.0	1.7	2.0	2.5	3.0	2.9	3.6	4.3	5.0	6.0	0.152	0.160		
L	0.4	0.6	0.6	1.0	1.0	1.4	1.6	1.8	2.5	2.8	3.8	4.0	0.094	0.089		
C	0.4	0.6	0.5	1.0	1.0	1.8	1.7	1.8	2.3	2.7	3.7	4.0	0.094	0.082		
N	0.4	0.4	0.4	0.7	0.6	1.0	1.2	1.6	1.5	1.8	2.8	3.0	0.066	0.066		
M	0.3	0.3	0.3	0.6	0.6	0.9	1.0	1.0	1.3	1.6	2.0	2.3	0.055	0.056		
D	0.3	0.3	0.3	0.5	0.6	0.6	1.0	1.0	1.3	1.5	2.1	2.1	0.052	0.053		
F	0.2	0.2	0.3	0.4	0.4	0.7	0.7	0.8	1.0	1.1	1.6	2.0	0.041	0.039		
E	0.2	0.2	0.2	0.4	0.4	0.6	0.6	0.7	0.9	1.0	1.4	1.6	0.035	0.033		
H	0.1	0.2	0.2	0.3	0.3	0.4	0.5	0.5	0.6	0.7	1.0	1.1	0.026	0.026		
B	0.1	0.2	0.2	0.3	0.3	0.3	0.4	0.5	0.5	0.6	0.9	1.0	0.024	0.021		

Validation benchmark test 2.2 JR											
i-th element	K^L_{ij}	a_{ij}	K^U_{ij}	j-th element	i-th element	K^L_{ij}	a_{ij}	K^U_{ij}	j-th element		
G	1.2	$\leq a_{1,2}$	≤ 1.3	A	L	1.5	$\leq a_{4,8}$	≤ 2.0	D		
G	1.2	$\leq a_{1,3}$	≤ 1.4	I	L	2.5	$\leq a_{4,9}$	≤ 3.0	F		
G	2.2	$\leq a_{1,4}$	≤ 2.4	L	L	2.8	$\leq a_{4,10}$	≤ 3.3	E		
G	2.2	$\leq a_{1,5}$	≤ 2.4	C	L	3.8	$\leq a_{4,11}$	≤ 4.2	H		
G	2.5	$\leq a_{1,6}$	≤ 2.6	N	L	3.9	$\leq a_{4,12}$	≤ 4.1	B		
G	3.0	$\leq a_{1,7}$	≤ 3.4	M	C	1.8	$\leq a_{5,6}$	≤ 2.2	N		
G	3.6	$\leq a_{1,8}$	≤ 4.0	D	C	1.4	$\leq a_{5,7}$	≤ 2.0	M		
G	5.0	$\leq a_{1,9}$	≤ 5.5	F	C	1.5	$\leq a_{5,8}$	≤ 1.8	D		
G	6.0	$\leq a_{1,10}$	≤ 6.2	E	C	2.2	$\leq a_{5,9}$	≤ 2.5	F		
G	7.6	$\leq a_{1,11}$	≤ 8.0	H	C	2.5	$\leq a_{5,10}$	≤ 3.0	E		
G	8.6	$\leq a_{1,12}$	≤ 9.0	B	C	3.7	$\leq a_{5,11}$	≤ 4.3	H		
A	1.2	$\leq a_{2,3}$	≤ 1.5	I	C	3.9	$\leq a_{5,12}$	≤ 4.1	B		
A	1.5	$\leq a_{2,4}$	≤ 2.0	L	N	1.0	$\leq a_{6,7}$	≤ 1.2	M		
A	1.7	$\leq a_{2,5}$	≤ 2.2	C	N	1.6	$\leq a_{6,8}$	≤ 2.0	D		
A	2.8	$\leq a_{2,6}$	≤ 3.1	N	N	1.2	$\leq a_{6,9}$	≤ 1.5	F		
A	2.9	$\leq a_{2,7}$	≤ 3.1	M	N	1.5	$\leq a_{6,10}$	≤ 1.8	E		
A	2.5	$\leq a_{2,8}$	≤ 3.5	D	N	2.8	$\leq a_{6,11}$	≤ 3.0	H		
A	4.5	$\leq a_{2,9}$	≤ 5.5	F	N	3.0	$\leq a_{6,12}$	≤ 3.2	B		
A	4.0	$\leq a_{2,10}$	≤ 5.0	E	M	1.0	$\leq a_{7,8}$	≤ 1.0	D		
A	4.5	$\leq a_{2,11}$	≤ 5.2	H	M	1.0	$\leq a_{7,9}$	≤ 1.4	F		
A	5.0	$\leq a_{2,12}$	≤ 5.5	B	M	1.5	$\leq a_{7,10}$	≤ 2.0	E		
I	1.7	$\leq a_{3,4}$	≤ 2.2	L	M	1.5	$\leq a_{7,11}$	≤ 2.0	H		
I	2.0	$\leq a_{3,5}$	≤ 2.6	C	M	2.0	$\leq a_{7,12}$	≤ 2.5	B		
I	2.5	$\leq a_{3,6}$	≤ 3.0	N	D	1.0	$\leq a_{8,9}$	≤ 1.5	F		
I	3.0	$\leq a_{3,7}$	≤ 3.0	M	D	1.5	$\leq a_{8,10}$	≤ 1.8	E		
I	2.5	$\leq a_{3,8}$	≤ 3.0	D	D	2.1	$\leq a_{8,11}$	≤ 2.3	H		
I	3.2	$\leq a_{3,9}$	≤ 3.6	F	D	2.0	$\leq a_{8,12}$	≤ 2.1	B		
I	4.0	$\leq a_{3,10}$	≤ 4.5	E	F	1.0	$\leq a_{9,10}$	≤ 1.1	E		
I	4.5	$\leq a_{3,11}$	≤ 5.0	H	F	1.5	$\leq a_{9,11}$	≤ 1.8	H		
I	5.5	$\leq a_{3,12}$	≤ 6.1	B	F	2.0	$\leq a_{9,12}$	≤ 2.2	B		
L	1.0	$\leq a_{4,5}$	≤ 1.1	C	E	1.3	$\leq a_{10,11}$	≤ 1.5	H		
L	1.0	$\leq a_{4,6}$	≤ 1.5	N	E	1.6	$\leq a_{10,12}$	≤ 2.0	B		
L	1.3	$\leq a_{4,7}$	≤ 1.6	M	H	1.0	$\leq a_{11,12}$	≤ 1.1	B		

Validation benchmark test 2.2 matrix $A^{Opt}_{test,2,2}$ (Weight obtained by remove the uncertain judgment ranges)																
$CI=$	0.007	G	A	I	L	C	N	M	D	F	E	H	B	$w^{Opt}_{test,2,2}$	rv	$Pe(w^{Opt}_{test,2,2})$
$RI=$	1.44															
$CR=$	0.005															
G		1.0	1.2	1.3	2.3	2.3	2.6	3.2	3.8	5.2	6.1	7.8	8.8	0.197	0.208	4.06%
A		0.8	1.0	1.3	2.0	1.9	2.9	3.0	3.1	4.7	4.6	4.9	6.7	0.168	0.167	
I		0.8	0.8	1.0	1.9	1.8	2.7	3.0	3.5	3.4	5.1	6.3	5.8	0.157	0.160	
L		0.4	0.5	0.5	1.0	1.0	1.3	1.5	2.0	2.4	3.1	4.0	4.0	0.091	0.089	
C		0.4	0.5	0.5	1.0	1.0	2.0	2.0	1.7	2.4	3.0	4.0	4.0	0.095	0.082	
N		0.4	0.3	0.4	0.8	0.5	1.0	1.1	1.7	1.4	1.7	2.9	3.1	0.064	0.066	
M		0.3	0.3	0.3	0.7	0.5	0.9	1.0	1.0	1.2	1.9	2.5	2.8	0.056	0.056	
D		0.3	0.3	0.3	0.5	0.6	0.6	1.0	1.0	1.5	1.6	2.2	2.1	0.051	0.053	
F		0.2	0.2	0.3	0.4	0.4	0.7	0.8	0.7	1.0	1.1	1.6	2.1	0.040	0.039	
E		0.2	0.2	0.2	0.3	0.3	0.6	0.5	0.6	1.0	1.0	1.4	1.8	0.034	0.033	
H		0.1	0.2	0.2	0.3	0.3	0.3	0.4	0.5	0.6	0.7	1.0	1.1	0.025	0.026	
B		0.1	0.1	0.2	0.3	0.3	0.3	0.4	0.5	0.5	0.6	1.0	1.0	0.022	0.021	

Validation benchmark test 2.2 JR (remove the uncertain judgment ranges)									
i-th element	K_{ij}^L	a_{ij}	K_{ij}^U	j-th element	i-th element	K_{ij}^L	a_{ij}	K_{ij}^U	j-th element
G	1.2	$\leq a_{1,2}$	≤ 1.3	A	L	1.0	$\leq a_{4,8}$	≤ 9.0	D
G	1.2	$\leq a_{1,3}$	≤ 1.4	I	L	1.0	$\leq a_{4,9}$	≤ 9.0	F
G	2.2	$\leq a_{1,4}$	≤ 2.4	L	L	2.8	$\leq a_{4,10}$	≤ 3.3	E
G	2.2	$\leq a_{1,5}$	≤ 2.4	C	L	3.8	$\leq a_{4,11}$	≤ 4.2	H
G	2.5	$\leq a_{1,6}$	≤ 2.6	N	L	3.9	$\leq a_{4,12}$	≤ 4.1	B
G	3.0	$\leq a_{1,7}$	≤ 3.4	M	C	1.8	$\leq a_{5,6}$	≤ 2.2	N
G	3.6	$\leq a_{1,8}$	≤ 4.0	D	C	1.0	$\leq a_{5,7}$	≤ 9.0	M
G	1.0	$\leq a_{1,9}$	≤ 9.0	F	C	1.5	$\leq a_{5,8}$	≤ 1.8	D
G	6.0	$\leq a_{1,10}$	≤ 6.2	E	C	2.2	$\leq a_{5,9}$	≤ 2.5	F
G	7.6	$\leq a_{1,11}$	≤ 8.0	H	C	1.0	$\leq a_{5,10}$	≤ 9.0	E
G	8.6	$\leq a_{1,12}$	≤ 9.0	B	C	3.7	$\leq a_{5,11}$	≤ 4.3	H
A	1.2	$\leq a_{2,3}$	≤ 1.5	I	C	3.9	$\leq a_{5,12}$	≤ 4.1	B
A	1.0	$\leq a_{2,4}$	≤ 9.0	L	N	1.0	$\leq a_{6,7}$	≤ 1.2	M
A	1.7	$\leq a_{2,5}$	≤ 2.2	C	N	1.6	$\leq a_{6,8}$	≤ 2.0	D
A	2.8	$\leq a_{2,6}$	≤ 3.1	N	N	1.2	$\leq a_{6,9}$	≤ 1.5	F
A	2.9	$\leq a_{2,7}$	≤ 3.1	M	N	1.5	$\leq a_{6,10}$	≤ 1.8	E
A	2.5	$\leq a_{2,8}$	≤ 3.5	D	N	2.8	$\leq a_{6,11}$	≤ 3.0	H
A	1.0	$\leq a_{2,9}$	≤ 9.0	F	N	3.0	$\leq a_{6,12}$	≤ 3.2	B
A	4.0	$\leq a_{2,10}$	≤ 5.0	E	M	1.0	$\leq a_{7,8}$	≤ 1.0	D
A	4.5	$\leq a_{2,11}$	≤ 5.2	H	M	1.0	$\leq a_{7,9}$	≤ 1.4	F
A	1.0	$\leq a_{2,12}$	≤ 9.0	B	M	1.0	$\leq a_{7,10}$	≤ 9.0	E
I	1.7	$\leq a_{3,4}$	≤ 2.2	L	M	1.0	$\leq a_{7,11}$	≤ 9.0	H
I	1.0	$\leq a_{3,5}$	≤ 9.0	C	M	1.0	$\leq a_{7,12}$	≤ 9.0	B
I	1.0	$\leq a_{3,6}$	≤ 9.0	N	D	1.0	$\leq a_{8,9}$	≤ 9.0	F
I	3.0	$\leq a_{3,7}$	≤ 3.0	M	D	1.5	$\leq a_{8,10}$	≤ 1.8	E
I	1.0	$\leq a_{3,8}$	≤ 9.0	D	D	2.1	$\leq a_{8,11}$	≤ 2.3	H
I	3.2	$\leq a_{3,9}$	≤ 3.6	F	D	2.0	$\leq a_{8,12}$	≤ 2.1	B
I	1.0	$\leq a_{3,10}$	≤ 9.0	E	F	1.0	$\leq a_{9,10}$	≤ 1.1	E
I	1.0	$\leq a_{3,11}$	≤ 9.0	H	F	1.5	$\leq a_{9,11}$	≤ 1.8	H
I	5.5	$\leq a_{3,12}$	≤ 6.1	B	F	2.0	$\leq a_{9,12}$	≤ 2.2	B
L	1.0	$\leq a_{4,5}$	≤ 1.1	C	E	1.3	$\leq a_{10,11}$	≤ 1.5	H
L	1.0	$\leq a_{4,6}$	≤ 1.5	N	E	1.0	$\leq a_{10,12}$	≤ 9.0	B
L	1.3	$\leq a_{4,7}$	≤ 1.6	M	H	1.0	$\leq a_{11,12}$	≤ 1.1	B

Validation benchmark test 2.3 matrix $A^{Opt}_{test,2.5}$																
$CI=$	0.004	G	A	I	L	C	N	M	D	F	E	H	B	$w^{Opt}_{test,2.3}$	rv	$Pe(w^{Opt}_{test,2})$
$RI=$	1.44															
$CR=$	0.003															
G	1.0	1.3	1.3	2.2	2.3	2.6	3.5	3.8	5.0	6.1	7.8	8.8	0.199	0.208		
A	0.8	1.0	1.0	1.6	2.0	2.8	3.0	3.0	4.1	4.6	5.1	5.4	0.158	0.167		
I	0.8	1.0	1.0	1.7	2.0	2.5	2.8	2.9	4.1	4.8	6.0	6.7	0.160	0.160		
L	0.4	0.6	0.6	1.0	1.1	1.5	1.8	2.5	2.3	4.5	3.7	3.9	0.103	0.089		
C	0.4	0.5	0.5	0.9	1.0	1.3	1.5	1.7	2.2	2.5	3.8	3.9	0.086	0.082		
N	0.4	0.4	0.4	0.7	0.8	1.0	1.2	1.3	1.7	1.9	2.6	2.9	0.066	0.066		
M	0.3	0.3	0.4	0.5	0.7	0.9	1.0	1.0	1.3	1.6	1.9	2.3	0.054	0.056		
D	0.3	0.3	0.3	0.4	0.6	0.8	1.0	1.0	1.2	1.5	2.1	2.1	0.051	0.053		
F	0.2	0.2	0.2	0.4	0.5	0.6	0.8	0.8	1.0	1.1	1.6	2.0	0.041	0.039		
E	0.2	0.2	0.2	0.2	0.4	0.5	0.6	0.7	0.9	1.0	1.3	1.6	0.033	0.033		
H	0.1	0.2	0.2	0.3	0.3	0.4	0.5	0.5	0.6	0.8	1.0	1.1	0.026	0.026		
B	0.1	0.2	0.1	0.3	0.3	0.3	0.4	0.5	0.5	0.6	0.9	1.0	0.023	0.021		

Validation benchmark test 2.3 JR										
i-th element	K^i_{ij}	a_{ij}	K^j_{ij}	j-th element	i-th element	K^i_{ij}	a_{ij}	K^j_{ij}	j-th element	
G	1.2	$\leq a_{1,2}$	≤ 1.3	A	L	2.5	$\leq a_{4,8}$	≤ 3.5	D	
G	1.2	$\leq a_{1,3}$	≤ 1.5	I	L	2.2	$\leq a_{4,9}$	≤ 2.4	F	
G	2.2	$\leq a_{1,4}$	≤ 2.4	L	L	4.5	$\leq a_{4,10}$	≤ 5.0	E	
G	2.2	$\leq a_{1,5}$	≤ 2.5	C	L	3.2	$\leq a_{4,11}$	≤ 3.8	H	
G	2.5	$\leq a_{1,6}$	≤ 2.6	N	L	3.5	$\leq a_{4,12}$	≤ 4.0	B	
G	3.4	$\leq a_{1,7}$	≤ 3.6	M	C	1.0	$\leq a_{5,6}$	≤ 1.5	N	
G	3.6	$\leq a_{1,8}$	≤ 4.0	D	C	1.3	$\leq a_{5,7}$	≤ 1.5	M	
G	4.8	$\leq a_{1,9}$	≤ 5.3	F	C	1.5	$\leq a_{5,8}$	≤ 1.8	D	
G	6.0	$\leq a_{1,10}$	≤ 6.2	E	C	2.0	$\leq a_{5,9}$	≤ 2.5	F	
G	7.6	$\leq a_{1,11}$	≤ 8.0	H	C	2.2	$\leq a_{5,10}$	≤ 2.6	E	
G	8.6	$\leq a_{1,12}$	≤ 9.0	B	C	3.7	$\leq a_{5,11}$	≤ 4.3	H	
A	1.0	$\leq a_{2,3}$	≤ 1.2	I	C	3.9	$\leq a_{5,12}$	≤ 4.0	B	
A	1.5	$\leq a_{2,4}$	≤ 2.0	L	N	1.0	$\leq a_{6,7}$	≤ 1.2	M	
A	2.0	$\leq a_{2,5}$	≤ 2.2	C	N	1.2	$\leq a_{6,8}$	≤ 1.4	D	
A	2.8	$\leq a_{2,6}$	≤ 3.1	N	N	1.6	$\leq a_{6,9}$	≤ 1.8	F	
A	2.9	$\leq a_{2,7}$	≤ 3.1	M	N	1.5	$\leq a_{6,10}$	≤ 2.0	E	
A	2.4	$\leq a_{2,8}$	≤ 3.2	D	N	2.4	$\leq a_{6,11}$	≤ 2.8	H	
A	3.8	$\leq a_{2,9}$	≤ 4.8	F	N	2.8	$\leq a_{6,12}$	≤ 3.0	B	
A	4.0	$\leq a_{2,10}$	≤ 5.0	E	M	1.0	$\leq a_{7,8}$	≤ 1.0	D	
A	4.5	$\leq a_{2,11}$	≤ 5.2	H	M	1.0	$\leq a_{7,9}$	≤ 1.3	F	
A	5.0	$\leq a_{2,12}$	≤ 5.5	B	M	1.5	$\leq a_{7,10}$	≤ 1.8	E	
I	1.7	$\leq a_{3,4}$	≤ 2.2	L	M	1.5	$\leq a_{7,11}$	≤ 2.0	H	
I	2.0	$\leq a_{3,5}$	≤ 2.6	C	M	2.0	$\leq a_{7,12}$	≤ 2.4	B	
I	2.4	$\leq a_{3,6}$	≤ 2.8	N	D	1.0	$\leq a_{8,9}$	≤ 1.4	F	
I	2.5	$\leq a_{3,7}$	≤ 2.9	M	D	1.4	$\leq a_{8,10}$	≤ 1.6	E	
I	2.6	$\leq a_{3,8}$	≤ 3.0	D	D	2.1	$\leq a_{8,11}$	≤ 2.3	H	
I	4.0	$\leq a_{3,9}$	≤ 4.2	F	D	2.0	$\leq a_{8,12}$	≤ 2.1	B	
I	4.5	$\leq a_{3,10}$	≤ 5.0	E	F	1.0	$\leq a_{9,10}$	≤ 1.1	E	
I	5.8	$\leq a_{3,11}$	≤ 6.2	H	F	1.5	$\leq a_{9,11}$	≤ 1.8	H	
I	6.5	$\leq a_{3,12}$	≤ 7.0	B	F	2.0	$\leq a_{9,12}$	≤ 2.2	B	
L	1.0	$\leq a_{4,5}$	≤ 1.1	C	E	1.2	$\leq a_{10,11}$	≤ 1.4	H	
L	1.2	$\leq a_{4,6}$	≤ 1.6	N	E	1.6	$\leq a_{10,12}$	≤ 2.0	B	
L	1.5	$\leq a_{4,7}$	≤ 2.0	M	H	1.0	$\leq a_{11,12}$	≤ 1.2	B	

Validation benchmark test 2.3 matrix $A^{Opt}_{test,2.3}$ (Weight obtained by remove the uncertain judgment ranges)																
CI=	0.002	G	A	I	L	C	N	M	D	F	E	H	B	$w^{Opt}_{test,2.3}$	rv	$Pe(w^{Opt}_{test,2})$ 2.88%
RI=	1.44															
CR=	0.002															
G	1.0	1.2	1.3	2.3	2.3	2.6	3.5	3.8	5.1	6.1	7.8	7.2	0.196	0.208		
A	0.8	1.0	1.1	1.9	2.1	2.9	3.0	3.0	4.8	5.2	6.3	6.9	0.171	0.167		
I	0.8	0.9	1.0	1.9	1.8	2.6	2.7	3.3	4.1	5.1	6.0	6.8	0.160	0.160		
L	0.4	0.5	0.5	1.0	1.0	1.4	1.7	1.8	2.3	2.8	3.5	4.5	0.092	0.089		
C	0.4	0.5	0.6	1.0	1.0	1.3	1.4	1.7	2.1	2.4	3.9	3.9	0.086	0.082		
N	0.4	0.3	0.4	0.7	0.8	1.0	1.1	1.3	1.7	1.9	2.6	2.9	0.065	0.066		
M	0.3	0.3	0.4	0.6	0.7	0.9	1.0	1.0	1.2	1.7	2.3	2.6	0.056	0.056		
D	0.3	0.3	0.3	0.6	0.6	0.8	1.0	1.0	1.4	1.5	2.2	2.1	0.052	0.053		
F	0.2	0.2	0.2	0.4	0.5	0.6	0.8	0.7	1.0	1.1	1.6	2.1	0.040	0.039		
E	0.2	0.2	0.2	0.4	0.4	0.5	0.6	0.7	0.9	1.0	1.3	1.6	0.034	0.033		
H	0.1	0.2	0.2	0.3	0.3	0.4	0.4	0.5	0.6	0.8	1.0	1.1	0.025	0.026		
B	0.1	0.1	0.1	0.2	0.3	0.3	0.4	0.5	0.5	0.6	0.9	1.0	0.023	0.021		

Validation benchmark test 2.3 JR (remove the uncertain judgment ranges)									
i-th element	K^L_{ij}	a_{ij}	K^U_{ij}	j-th element	i-th element	K^L_{ij}	a_{ij}	K^U_{ij}	j-th element
G	1.2	$\leq a_{1,2}$	≤ 1.3	A	L	1.0	$\leq a_{4,8}$	≤ 9.0	D
G	1.2	$\leq a_{1,3}$	≤ 1.5	I	L	2.2	$\leq a_{4,9}$	≤ 2.4	F
G	2.2	$\leq a_{1,4}$	≤ 2.4	L	L	1.0	$\leq a_{4,10}$	≤ 9.0	E
G	2.2	$\leq a_{1,5}$	≤ 2.5	C	L	3.2	$\leq a_{4,11}$	≤ 3.8	H
G	2.5	$\leq a_{1,6}$	≤ 2.6	N	L	1.0	$\leq a_{4,12}$	≤ 9.0	B
G	3.4	$\leq a_{1,7}$	≤ 3.6	M	C	1.0	$\leq a_{5,6}$	≤ 1.5	N
G	3.6	$\leq a_{1,8}$	≤ 4.0	D	C	1.3	$\leq a_{5,7}$	≤ 1.5	M
G	4.8	$\leq a_{1,9}$	≤ 5.3	F	C	1.5	$\leq a_{5,8}$	≤ 1.8	D
G	6.0	$\leq a_{1,10}$	≤ 6.2	E	C	1.0	$\leq a_{5,9}$	≤ 9.0	F
G	7.6	$\leq a_{1,11}$	≤ 8.0	H	C	2.2	$\leq a_{5,10}$	≤ 2.6	E
G	1.0	$\leq a_{1,12}$	≤ 9.0	B	C	3.7	$\leq a_{5,11}$	≤ 4.3	H
A	1.0	$\leq a_{2,3}$	≤ 1.2	I	C	3.9	$\leq a_{5,12}$	≤ 4.0	B
A	1.0	$\leq a_{2,4}$	≤ 9.0	L	N	1.0	$\leq a_{6,7}$	≤ 1.2	M
A	2.0	$\leq a_{2,5}$	≤ 2.2	C	N	1.2	$\leq a_{6,8}$	≤ 1.4	D
A	2.8	$\leq a_{2,6}$	≤ 3.1	N	N	1.6	$\leq a_{6,9}$	≤ 1.8	F
A	2.9	$\leq a_{2,7}$	≤ 3.1	M	N	1.0	$\leq a_{6,10}$	≤ 9.0	E
A	2.4	$\leq a_{2,8}$	≤ 3.2	D	N	2.4	$\leq a_{6,11}$	≤ 2.8	H
A	1.0	$\leq a_{2,9}$	≤ 9.0	F	N	2.8	$\leq a_{6,12}$	≤ 3.0	B
A	1.0	$\leq a_{2,10}$	≤ 9.0	E	M	1.0	$\leq a_{7,8}$	≤ 1.0	D
A	1.0	$\leq a_{2,11}$	≤ 9.0	H	M	1.0	$\leq a_{7,9}$	≤ 1.3	F
A	1.0	$\leq a_{2,12}$	≤ 9.0	B	M	1.5	$\leq a_{7,10}$	≤ 1.8	E
I	1.7	$\leq a_{3,4}$	≤ 2.2	L	M	1.0	$\leq a_{7,11}$	≤ 9.0	H
I	1.0	$\leq a_{3,5}$	≤ 9.0	C	M	1.0	$\leq a_{7,12}$	≤ 9.0	B
I	2.4	$\leq a_{3,6}$	≤ 2.8	N	D	1.0	$\leq a_{8,9}$	≤ 9.0	F
I	2.5	$\leq a_{3,7}$	≤ 2.9	M	D	1.4	$\leq a_{8,10}$	≤ 1.6	E
I	1.0	$\leq a_{3,8}$	≤ 9.0	D	D	2.1	$\leq a_{8,11}$	≤ 2.3	H
I	4.0	$\leq a_{3,9}$	≤ 4.2	F	D	2.0	$\leq a_{8,12}$	≤ 2.1	B
I	1.0	$\leq a_{3,10}$	≤ 9.0	E	F	1.0	$\leq a_{9,10}$	≤ 1.1	E
I	5.8	$\leq a_{3,11}$	≤ 6.2	H	F	1.5	$\leq a_{9,11}$	≤ 1.8	H
I	1.0	$\leq a_{3,12}$	≤ 9.0	B	F	2.0	$\leq a_{9,12}$	≤ 2.2	B
L	1.0	$\leq a_{4,5}$	≤ 1.1	C	E	1.2	$\leq a_{10,11}$	≤ 1.4	H
L	1.2	$\leq a_{4,6}$	≤ 1.6	N	E	1.0	$\leq a_{10,12}$	≤ 9.0	B
L	1.5	$\leq a_{4,7}$	≤ 2.0	M	H	1.0	$\leq a_{11,12}$	≤ 1.2	B

Validation benchmark test 2.4 matrix $A^{Opt}_{test,2.4}$																	
$CI=$	0.015	G	A	I	L	C	N	M	D	F	E	H	B	$w^{Opt}_{test,2.4}$	rv	$Pe(w^{Opt}_{test,2})$	2.30%
$RI=$	1.44																
$CR=$	0.010																
G	1.0	1.2	1.3	2.5	2.6	3.2	3.7	3.8	5.7	6.2	7.7	8.8	0.208	0.208			
A	0.8	1.0	1.0	2.8	2.0	2.5	3.0	3.3	3.9	5.0	6.2	7.0	0.170	0.167			
I	0.8	1.0	1.0	1.9	2.1	2.6	2.8	3.2	4.1	4.8	6.5	7.1	0.164	0.160			
L	0.4	0.4	0.5	1.0	1.1	1.3	1.6	1.6	2.2	2.5	3.3	3.7	0.083	0.089			
C	0.4	0.5	0.5	0.9	1.0	1.2	1.4	1.6	2.1	2.4	3.3	3.5	0.081	0.082			
N	0.3	0.4	0.4	0.8	0.8	1.0	1.1	1.3	1.7	1.9	2.7	2.9	0.066	0.066			
M	0.3	0.3	0.4	0.6	0.7	0.9	1.0	1.1	1.4	1.7	2.1	2.4	0.056	0.056			
D	0.3	0.3	0.3	0.6	0.6	0.8	0.9	1.0	1.3	1.6	2.0	2.2	0.052	0.053			
F	0.2	0.3	0.2	0.5	0.5	0.6	0.7	0.8	1.0	1.2	1.6	1.7	0.039	0.039			
E	0.2	0.2	0.2	0.4	0.4	0.5	0.6	0.6	0.8	1.0	1.3	1.6	0.034	0.033			
H	0.1	0.2	0.2	0.3	0.3	0.4	0.5	0.5	0.6	0.8	1.0	1.1	0.026	0.026			
B	0.1	0.1	0.1	0.3	0.3	0.3	0.4	0.4	0.6	0.6	0.9	1.0	0.023	0.021			

Validation benchmark test 2.4 JR									
i-th element	K^L_{ij}	a_{ij}	K^U_{ij}	j-th element	i-th element	K^L_{ij}	a_{ij}	K^U_{ij}	j-th element
G	1.2	$\leq a_{1,2}$	≤ 1.4	A	L	1.5	$\leq a_{4,8}$	≤ 2.0	D
G	1.0	$\leq a_{1,3}$	≤ 2.2	I	L	2.0	$\leq a_{4,9}$	≤ 3.0	F
G	2.2	$\leq a_{1,4}$	≤ 3.0	L	L	2.0	$\leq a_{4,10}$	≤ 3.2	E
G	2.2	$\leq a_{1,5}$	≤ 3.0	C	L	3.0	$\leq a_{4,11}$	≤ 4.0	H
G	3.0	$\leq a_{1,6}$	≤ 3.5	N	L	3.5	$\leq a_{4,12}$	≤ 4.0	B
G	3.5	$\leq a_{1,7}$	≤ 4.0	M	C	1.0	$\leq a_{5,6}$	≤ 1.5	N
G	3.5	$\leq a_{1,8}$	≤ 4.0	D	C	1.0	$\leq a_{5,7}$	≤ 1.5	M
G	5.0	$\leq a_{1,9}$	≤ 7.0	F	C	1.5	$\leq a_{5,8}$	≤ 2.0	D
G	6.0	$\leq a_{1,10}$	≤ 6.5	E	C	2.0	$\leq a_{5,9}$	≤ 3.0	F
G	7.0	$\leq a_{1,11}$	≤ 8.0	H	C	2.0	$\leq a_{5,10}$	≤ 3.0	E
G	8.5	$\leq a_{1,12}$	≤ 9.0	B	C	3.0	$\leq a_{5,11}$	≤ 4.0	H
A	1.0	$\leq a_{2,3}$	≤ 1.0	I	N	3.4	$\leq a_{5,12}$	≤ 3.6	B
A	2.8	$\leq a_{2,4}$	≤ 3.0	L	N	1.0	$\leq a_{6,7}$	≤ 1.2	M
A	1.9	$\leq a_{2,5}$	≤ 2.1	C	N	1.0	$\leq a_{6,8}$	≤ 1.5	D
A	2.2	$\leq a_{2,6}$	≤ 2.6	N	N	1.5	$\leq a_{6,9}$	≤ 2.0	F
A	2.6	$\leq a_{2,7}$	≤ 3.4	M	N	1.5	$\leq a_{6,10}$	≤ 2.2	E
A	3.0	$\leq a_{2,8}$	≤ 3.5	D	N	2.5	$\leq a_{6,11}$	≤ 3.2	H
A	2.0	$\leq a_{2,9}$	≤ 4.0	F	N	2.8	$\leq a_{6,12}$	≤ 3.2	B
A	4.8	$\leq a_{2,10}$	≤ 5.2	E	M	1.0	$\leq a_{7,8}$	≤ 1.5	D
A	6.0	$\leq a_{2,11}$	≤ 6.4	H	M	1.0	$\leq a_{7,9}$	≤ 2.0	F
A	6.8	$\leq a_{2,12}$	≤ 7.2	B	M	1.5	$\leq a_{7,10}$	≤ 2.0	E
I	1.5	$\leq a_{3,4}$	≤ 2.0	L	M	1.5	$\leq a_{7,11}$	≤ 2.2	H
I	2.0	$\leq a_{3,5}$	≤ 2.5	C	M	2.2	$\leq a_{7,12}$	≤ 2.5	B
I	2.5	$\leq a_{3,6}$	≤ 3.0	N	D	1.2	$\leq a_{8,9}$	≤ 1.5	F
I	2.5	$\leq a_{3,7}$	≤ 3.0	M	D	1.5	$\leq a_{8,10}$	≤ 2.0	E
I	2.5	$\leq a_{3,8}$	≤ 5.0	D	D	1.8	$\leq a_{8,11}$	≤ 2.2	H
I	4.0	$\leq a_{3,9}$	≤ 4.1	F	D	2.0	$\leq a_{8,12}$	≤ 2.5	B
I	4.5	$\leq a_{3,10}$	≤ 5.0	E	F	1.0	$\leq a_{9,10}$	≤ 1.5	E
I	6.0	$\leq a_{3,11}$	≤ 7.0	H	F	1.5	$\leq a_{9,11}$	≤ 2.0	H
I	6.5	$\leq a_{3,12}$	≤ 7.5	B	F	1.5	$\leq a_{9,12}$	≤ 2.0	B
L	1.0	$\leq a_{4,5}$	≤ 1.2	C	E	1.0	$\leq a_{10,11}$	≤ 1.5	H
L	1.2	$\leq a_{4,6}$	≤ 1.5	N	E	1.5	$\leq a_{10,12}$	≤ 2.0	B
L	1.5	$\leq a_{4,7}$	≤ 2.0	M	H	1.0	$\leq a_{11,12}$	≤ 1.2	B

Validation benchmark test 2.4 matrix $A_{test,2.4}^{Opt}$ (Weight obtained by remove the uncertain judgment ranges)																
$CI=$	0.003	G	A	I	L	C	N	M	D	F	E	H	B	$w_{test,2.4}^{Opt}$	rv	$Pe(w_{test,2}^{Opt})$
$RI=$	1.44															
$CR=$	0.002															
G		1.0	1.3	1.3	2.6	2.4	3.2	3.9	4.3	5.5	6.2	7.3	7.7	0.204	0.208	4.10%
A		0.8	1.0	1.0	2.9	2.0	2.4	3.1	3.6	4.7	5.0	6.2	7.0	0.172	0.167	
I		0.8	1.0	1.0	2.1	2.3	2.7	3.5	3.9	4.1	4.8	6.4	7.5	0.172	0.160	
L		0.4	0.4	0.5	1.0	1.1	1.3	1.6	1.8	2.4	2.5	3.4	3.7	0.083	0.089	
C		0.4	0.5	0.4	0.9	1.0	1.3	1.4	1.8	2.2	2.6	3.6	3.9	0.083	0.082	
N		0.3	0.4	0.4	0.8	0.8	1.0	1.1	1.3	1.7	1.9	2.4	3.0	0.064	0.066	
M		0.3	0.3	0.3	0.6	0.7	0.9	1.0	1.2	1.5	1.7	2.1	2.4	0.054	0.056	
D		0.2	0.3	0.3	0.6	0.6	0.8	0.9	1.0	1.3	1.6	1.9	2.3	0.048	0.053	
F		0.2	0.2	0.2	0.4	0.5	0.6	0.7	0.7	1.0	1.2	1.6	1.7	0.038	0.039	
E		0.2	0.2	0.2	0.4	0.4	0.5	0.6	0.6	0.9	1.0	1.3	1.6	0.033	0.033	
H		0.1	0.2	0.2	0.3	0.3	0.4	0.5	0.5	0.6	0.8	1.0	1.1	0.026	0.026	
B		0.1	0.1	0.1	0.3	0.3	0.3	0.4	0.4	0.6	0.6	0.9	1.0	0.023	0.021	

Validation benchmark test 2.4 JR (remove the uncertain judgment ranges)									
i-th element	K_{ij}^L	a_{ij}	K_{ij}^U	j-th element	i-th element	K_{ij}^L	a_{ij}	K_{ij}^U	j-th element
G	1.2	$\leq a_{1,2}$	≤ 1.4	A	L	1.5	$\leq a_{4,8}$	≤ 2.0	D
G	1.0	$\leq a_{1,3}$	≤ 2.2	I	L	2.0	$\leq a_{4,9}$	≤ 3.0	F
G	2.2	$\leq a_{1,4}$	≤ 3.0	L	L	1.0	$\leq a_{4,10}$	≤ 9.0	E
G	2.2	$\leq a_{1,5}$	≤ 3.0	C	L	1.0	$\leq a_{4,11}$	≤ 9.0	H
G	1.0	$\leq a_{1,6}$	≤ 9.0	N	L	3.5	$\leq a_{4,12}$	≤ 4.0	B
G	1.0	$\leq a_{1,7}$	≤ 9.0	M	C	1.0	$\leq a_{5,6}$	≤ 1.5	N
G	1.0	$\leq a_{1,8}$	≤ 9.0	D	C	1.0	$\leq a_{5,7}$	≤ 1.5	M
G	1.0	$\leq a_{1,9}$	≤ 9.0	F	C	1.5	$\leq a_{5,8}$	≤ 2.0	D
G	1.0	$\leq a_{1,10}$	≤ 9.0	E	C	1.0	$\leq a_{5,9}$	≤ 9.0	F
G	1.0	$\leq a_{1,11}$	≤ 9.0	H	C	1.0	$\leq a_{5,10}$	≤ 9.0	E
G	1.0	$\leq a_{1,12}$	≤ 9.0	B	C	1.0	$\leq a_{5,11}$	≤ 9.0	H
A	1.0	$\leq a_{2,3}$	≤ 1.0	I	C	1.0	$\leq a_{5,12}$	≤ 9.0	B
A	2.8	$\leq a_{2,4}$	≤ 3.0	L	N	1.0	$\leq a_{6,7}$	≤ 1.2	M
A	1.9	$\leq a_{2,5}$	≤ 2.1	C	N	1.0	$\leq a_{6,8}$	≤ 1.5	D
A	2.2	$\leq a_{2,6}$	≤ 2.6	N	N	1.5	$\leq a_{6,9}$	≤ 2.0	F
A	2.6	$\leq a_{2,7}$	≤ 3.4	M	N	1.5	$\leq a_{6,10}$	≤ 2.2	E
A	1.0	$\leq a_{2,8}$	≤ 9.0	D	N	1.0	$\leq a_{6,11}$	≤ 9.0	H
A	1.0	$\leq a_{2,9}$	≤ 9.0	F	N	2.8	$\leq a_{6,12}$	≤ 3.2	B
A	4.8	$\leq a_{2,10}$	≤ 5.2	E	M	1.0	$\leq a_{7,8}$	≤ 1.5	D
A	6.0	$\leq a_{2,11}$	≤ 6.4	H	M	1.0	$\leq a_{7,9}$	≤ 2.0	F
A	6.8	$\leq a_{2,12}$	≤ 7.2	B	M	1.5	$\leq a_{7,10}$	≤ 2.0	E
I	1.0	$\leq a_{3,4}$	≤ 9.0	L	M	1.5	$\leq a_{7,11}$	≤ 2.2	H
I	1.0	$\leq a_{3,5}$	≤ 9.0	C	M	2.2	$\leq a_{7,12}$	≤ 2.5	B
I	1.0	$\leq a_{3,6}$	≤ 9.0	N	D	1.2	$\leq a_{8,9}$	≤ 1.5	F
I	1.0	$\leq a_{3,7}$	≤ 9.0	M	D	1.5	$\leq a_{8,10}$	≤ 2.0	E
I	1.0	$\leq a_{3,8}$	≤ 9.0	D	D	1.8	$\leq a_{8,11}$	≤ 2.2	H
I	4.0	$\leq a_{3,9}$	≤ 4.1	F	D	1.0	$\leq a_{8,12}$	≤ 9.0	B
I	4.5	$\leq a_{3,10}$	≤ 5.0	E	F	1.0	$\leq a_{9,10}$	≤ 1.5	E
I	6.0	$\leq a_{3,11}$	≤ 7.0	H	F	1.5	$\leq a_{9,11}$	≤ 2.0	H
I	1.0	$\leq a_{3,12}$	≤ 9.0	B	F	1.5	$\leq a_{9,12}$	≤ 2.0	B
L	1.0	$\leq a_{4,5}$	≤ 1.2	C	E	1.0	$\leq a_{10,11}$	≤ 1.5	H
L	1.2	$\leq a_{4,6}$	≤ 1.5	N	E	1.5	$\leq a_{10,12}$	≤ 2.0	B
L	1.5	$\leq a_{4,7}$	≤ 2.0	M	H	1.0	$\leq a_{11,12}$	≤ 1.2	B

Validation benchmark test 2.5 matrix $A^{Opt}_{test,2.5}$																
$CI=$	0.021	G	A	I	L	C	N	M	D	F	E	H	B	$w^{Opt}_{test,2.5}$	rv	$Pe(w^{Opt}_{test,2})$ 4.10%
$RI=$	1.44															
$CR=$	0.015															
G		1.0	1.2	1.3	2.3	2.4	3.2	3.8	3.9	5.2	6.1	7.7	8.7	0.207	0.208	
A		0.8	1.0	1.1	1.8	1.9	2.5	3.0	3.1	4.2	5.8	4.9	6.0	0.165	0.167	
I		0.7	0.9	1.0	1.7	1.4	2.4	2.8	2.9	4.0	4.5	6.0	6.7	0.153	0.160	
L		0.4	0.5	0.6	1.0	1.0	1.3	1.6	1.6	2.2	2.6	3.3	3.6	0.089	0.089	
C		0.4	0.5	0.7	1.0	1.0	1.2	1.5	1.6	2.2	2.3	3.1	3.4	0.086	0.082	
N		0.3	0.4	0.4	0.8	0.8	1.0	1.2	1.2	1.6	1.8	2.2	2.4	0.065	0.066	
M		0.3	0.3	0.4	0.6	0.7	0.9	1.0	1.0	1.3	1.5	1.9	2.1	0.055	0.056	
D		0.3	0.3	0.3	0.6	0.6	0.8	1.0	1.0	1.3	1.5	1.9	2.2	0.053	0.053	
F		0.2	0.2	0.2	0.4	0.5	0.6	0.8	0.8	1.0	1.1	1.3	1.4	0.039	0.039	
E		0.2	0.2	0.2	0.4	0.4	0.5	0.7	0.7	0.9	1.0	1.3	1.6	0.035	0.033	
H		0.1	0.2	0.2	0.3	0.3	0.5	0.5	0.5	0.8	0.8	1.0	1.1	0.028	0.026	
B		0.1	0.2	0.2	0.3	0.3	0.4	0.5	0.4	0.7	0.6	0.9	1.0	0.025	0.021	

Validation benchmark test2.5 JR										
i-th element	K^L_{ij}	a_{ij}	K^U_{ij}	j-th element	i-th element	K^L_{ij}	a_{ij}	K^U_{ij}	j-th element	
G	1.1	$\leq a_{1,2}$	≤ 1.2	A	L	1.5	$\leq a_{4,8}$	≤ 1.7	D	
G	1.2	$\leq a_{1,3}$	≤ 1.4	I	L	2.1	$\leq a_{4,9}$	≤ 2.3	F	
G	2.1	$\leq a_{1,4}$	≤ 2.3	L	L	2.5	$\leq a_{4,10}$	≤ 2.9	E	
G	2.3	$\leq a_{1,5}$	≤ 2.5	C	L	3.3	$\leq a_{4,11}$	≤ 3.5	H	
G	1.0	$\leq a_{1,6}$	≤ 3.5	N	L	3.6	$\leq a_{4,12}$	≤ 4.0	B	
G	3.5	$\leq a_{1,7}$	≤ 4.0	M	C	1.0	$\leq a_{5,6}$	≤ 1.2	N	
G	3.8	$\leq a_{1,8}$	≤ 4.0	D	C	1.3	$\leq a_{5,7}$	≤ 1.5	M	
G	5.0	$\leq a_{1,9}$	≤ 5.3	F	C	1.0	$\leq a_{5,8}$	≤ 1.6	D	
G	6.0	$\leq a_{1,10}$	≤ 6.3	E	C	2.0	$\leq a_{5,9}$	≤ 2.3	F	
G	7.5	$\leq a_{1,11}$	≤ 8.0	H	C	2.0	$\leq a_{5,10}$	≤ 2.3	E	
G	8.5	$\leq a_{1,12}$	≤ 9.0	B	C	3.0	$\leq a_{5,11}$	≤ 3.5	H	
A	1.1	$\leq a_{2,3}$	≤ 1.2	I	C	3.0	$\leq a_{5,12}$	≤ 3.5	B	
A	1.4	$\leq a_{2,4}$	≤ 2.0	L	N	1.1	$\leq a_{6,7}$	≤ 1.2	M	
A	1.5	$\leq a_{2,5}$	≤ 2.3	C	N	1.2	$\leq a_{6,8}$	≤ 1.3	D	
A	2.3	$\leq a_{2,6}$	≤ 2.5	N	N	1.4	$\leq a_{6,9}$	≤ 1.6	F	
A	2.9	$\leq a_{2,7}$	≤ 3.1	M	N	1.7	$\leq a_{6,10}$	≤ 1.9	E	
A	3.0	$\leq a_{2,8}$	≤ 3.3	D	N	2.0	$\leq a_{6,11}$	≤ 2.2	H	
A	4.0	$\leq a_{2,9}$	≤ 4.3	F	N	2.2	$\leq a_{6,12}$	≤ 2.4	B	
A	5.8	$\leq a_{2,10}$	≤ 6.3	E	M	1.0	$\leq a_{7,8}$	≤ 1.1	D	
A	4.7	$\leq a_{2,11}$	≤ 4.9	H	M	1.1	$\leq a_{7,9}$	≤ 1.3	F	
A	5.8	$\leq a_{2,12}$	≤ 6.0	B	M	1.4	$\leq a_{7,10}$	≤ 1.6	E	
I	1.5	$\leq a_{3,4}$	≤ 2.0	L	M	1.8	$\leq a_{7,11}$	≤ 2.0	H	
I	1.3	$\leq a_{3,5}$	≤ 1.4	C	M	2.0	$\leq a_{7,12}$	≤ 2.2	B	
I	2.3	$\leq a_{3,6}$	≤ 2.5	N	D	1.1	$\leq a_{8,9}$	≤ 1.3	F	
I	2.5	$\leq a_{3,7}$	≤ 3.0	M	D	1.3	$\leq a_{8,10}$	≤ 1.5	E	
I	2.8	$\leq a_{3,8}$	≤ 3.2	D	D	1.9	$\leq a_{8,11}$	≤ 2.1	H	
I	4.0	$\leq a_{3,9}$	≤ 4.2	F	D	2.2	$\leq a_{8,12}$	≤ 2.3	B	
I	4.2	$\leq a_{3,10}$	≤ 5.0	E	F	1.1	$\leq a_{9,10}$	≤ 1.2	E	
I	6.0	$\leq a_{3,11}$	≤ 6.3	H	F	1.2	$\leq a_{9,11}$	≤ 1.3	H	
I	6.5	$\leq a_{3,12}$	≤ 7.3	B	F	1.3	$\leq a_{9,12}$	≤ 1.4	B	
L	1.0	$\leq a_{4,5}$	≤ 1.1	C	E	1.3	$\leq a_{10,11}$	≤ 1.5	H	
L	1.0	$\leq a_{4,6}$	≤ 1.3	N	E	1.6	$\leq a_{10,12}$	≤ 1.8	B	
L	1.3	$\leq a_{4,7}$	≤ 1.6	M	H	1.0	$\leq a_{11,12}$	≤ 1.1	B	

Validation benchmark test 2.5 matrix $A_{test,2.5}^{Opt}$ (Weight obtained by remove the uncertain judgment ranges)																
$CI=$	0.003	G	A	I	L	C	N	M	D	F	E	H	B	$w_{test,2.5}^{Opt}$	rv	$Pe(w_{test,2}^{Opt})$
$RI=$	1.44															
$CR=$	0.002															
G		1.0	1.2	1.3	2.2	2.4	3.0	3.8	3.9	5.1	5.7	6.6	7.0	0.199	0.208	5.50%
A		0.9	1.0	1.1	1.9	2.1	2.4	3.0	3.1	4.4	5.1	4.8	5.9	0.167	0.167	
I		0.8	0.9	1.0	1.9	1.4	2.4	2.8	2.8	4.1	4.7	5.7	6.1	0.154	0.160	
L		0.5	0.5	0.5	1.0	1.1	1.4	1.7	1.6	2.2	2.4	3.2	3.7	0.090	0.089	
C		0.4	0.5	0.7	1.0	1.0	1.2	1.5	1.6	2.2	2.3	2.8	3.2	0.085	0.082	
N		0.3	0.4	0.4	0.7	0.8	1.0	1.2	1.2	1.5	1.9	2.1	2.3	0.065	0.066	
M		0.3	0.3	0.4	0.6	0.7	0.9	1.0	1.0	1.2	1.5	1.9	2.1	0.055	0.056	
D		0.3	0.3	0.4	0.6	0.6	0.8	1.0	1.0	1.2	1.4	2.0	2.2	0.054	0.053	
F		0.2	0.2	0.2	0.5	0.4	0.7	0.8	0.8	1.0	1.1	1.3	1.4	0.040	0.039	
E		0.2	0.2	0.2	0.4	0.4	0.5	0.7	0.7	0.9	1.0	1.4	1.7	0.037	0.033	
H		0.2	0.2	0.2	0.3	0.4	0.5	0.5	0.5	0.8	0.7	1.0	1.1	0.029	0.026	
B		0.1	0.2	0.2	0.3	0.3	0.4	0.5	0.4	0.7	0.6	0.9	1.0	0.026	0.021	

Validation benchmark test 2.5 JR (remove the uncertain judgment ranges)									
i-th element	K_{ij}^L	a_{ij}	K_{ij}^U	j-th element	i-th element	K_{ij}^L	a_{ij}	K_{ij}^U	j-th element
G	$1.1 \leq a_{1,2} \leq 1.2$			A	L	$1.5 \leq a_{4,8} \leq 1.7$			D
G	$1.2 \leq a_{1,3} \leq 1.4$			I	L	$2.1 \leq a_{4,9} \leq 2.3$			F
G	$2.1 \leq a_{1,4} \leq 2.3$			L	L	$1.0 \leq a_{4,10} \leq 9.0$			E
G	$2.3 \leq a_{1,5} \leq 2.5$			C	L	$1.0 \leq a_{4,11} \leq 9.0$			H
G	$1.0 \leq a_{1,6} \leq 9.0$			N	L	$1.0 \leq a_{4,12} \leq 9.0$			B
G	$1.0 \leq a_{1,7} \leq 9.0$			M	C	$1.2 \leq a_{5,6} \leq 1.2$			N
G	$3.8 \leq a_{1,8} \leq 4.0$			D	C	$1.4 \leq a_{5,7} \leq 1.5$			M
G	$1.0 \leq a_{1,9} \leq 9.0$			F	C	$1.5 \leq a_{5,8} \leq 1.6$			D
G	$1.0 \leq a_{1,10} \leq 9.0$			E	C	$2.2 \leq a_{5,9} \leq 2.3$			F
G	$1.0 \leq a_{1,11} \leq 9.0$			H	C	$2.2 \leq a_{5,10} \leq 2.3$			E
G	$1.0 \leq a_{1,12} \leq 9.0$			B	C	$1.0 \leq a_{5,11} \leq 9.0$			H
A	$1.1 \leq a_{2,3} \leq 1.2$			I	C	$1.0 \leq a_{5,12} \leq 9.0$			B
A	$1.0 \leq a_{2,4} \leq 9.0$			L	N	$1.1 \leq a_{6,7} \leq 1.2$			M
A	$1.0 \leq a_{2,5} \leq 9.0$			C	N	$1.2 \leq a_{6,8} \leq 1.3$			D
A	$2.3 \leq a_{2,6} \leq 2.5$			N	N	$1.4 \leq a_{6,9} \leq 1.6$			F
A	$2.9 \leq a_{2,7} \leq 3.1$			M	N	$1.0 \leq a_{6,10} \leq 9.0$			E
A	$1.0 \leq a_{2,8} \leq 9.0$			D	N	$2.0 \leq a_{6,11} \leq 2.2$			H
A	$1.0 \leq a_{2,9} \leq 9.0$			F	N	$2.2 \leq a_{6,12} \leq 2.4$			B
A	$1.0 \leq a_{2,10} \leq 9.0$			E	M	$1.0 \leq a_{7,8} \leq 1.1$			D
A	$4.7 \leq a_{2,11} \leq 4.9$			H	M	$1.1 \leq a_{7,9} \leq 1.3$			F
A	$5.8 \leq a_{2,12} \leq 6.0$			B	M	$1.4 \leq a_{7,10} \leq 1.6$			E
I	$1.0 \leq a_{3,4} \leq 9.0$			L	M	$1.8 \leq a_{7,11} \leq 2.0$			H
I	$1.3 \leq a_{3,5} \leq 1.4$			C	M	$2.0 \leq a_{7,12} \leq 2.2$			B
I	$2.3 \leq a_{3,6} \leq 2.5$			N	D	$1.1 \leq a_{8,9} \leq 1.3$			F
I	$1.0 \leq a_{3,7} \leq 9.0$			M	D	$1.3 \leq a_{8,10} \leq 1.5$			E
I	$1.0 \leq a_{3,8} \leq 9.0$			D	D	$1.9 \leq a_{8,11} \leq 2.1$			H
I	$4.0 \leq a_{3,9} \leq 4.2$			F	D	$2.2 \leq a_{8,12} \leq 2.3$			B
I	$1.0 \leq a_{3,10} \leq 9.0$			E	F	$1.1 \leq a_{9,10} \leq 1.2$			E
I	$1.0 \leq a_{3,11} \leq 9.0$			H	F	$1.2 \leq a_{9,11} \leq 1.3$			H
I	$1.0 \leq a_{3,12} \leq 9.0$			B	F	$1.3 \leq a_{9,12} \leq 1.4$			B
L	$1.0 \leq a_{4,5} \leq 1.1$			C	E	$1.3 \leq a_{10,11} \leq 1.5$			H
L	$1.0 \leq a_{4,6} \leq 9.0$			N	E	$1.6 \leq a_{10,12} \leq 1.8$			B
L	$1.0 \leq a_{4,7} \leq 9.0$			M	H	$1.0 \leq a_{11,12} \leq 1.1$			B

ATTACHMENTS 2

General Matrix of Damages

Photo: Building main facade

Building Condition Rating

Surveyed damage

CITY		ADDRESS		MATRIX OF DAMAGE		Cod	Ox			Cr			Gi			Df			De		
							R.C. Corrosion			Cracking pattern			Defect in giuntion and detachment			Component deformation			Plaster or finising decay		
Photo		Registry data		Total area: - m ² N° of Floors: - Area of single floor: - m ² Construction typology: - N° of buildings blocks: - Building Condition Rating: -		Cod	Ox1	Ox2	Ox3	Cr1	Cr2	Cr3	Gi1	Gi2	Gi3	Df1	Df2	Df3	De1	De2	De3
							Tech. Unit		Element		Sub-element		Cracks caused by rebar corrosion	Spalling	Heavy concrete spalling	Thin cracks	Medium cracks	Wide or active cracks	Defects at junction	Detachment of elements	Brick blocks falling down
Code	Type	Code	Typology	CCr	Code	Component															
S	Str.	S2	Structural element	-	S2.2	Column															
				-	S2.3	Beam															
L	Load b.	L1	Slab	-	L1.4	Balcony or projection															
		L2	Connection	-	L2.1	Staircase															
N	Non load bearing	N1	Facade envelope	-	N1.1	Curtain wall															
				-	N1.2	Windows fixture															
		N2	External wall	-	N2.1	External R.C. wall															
				-	N2.2	External brick wall															
		N4	Other	-	N4.1	Joint between elements															

Component Condition Rating

Damaged Component

Number of surveyed damages

SCU	BUILDINGS		School Gurieli		MATRIX OF DAMAGE		Cost for repair Test	Ox			Cr			Gi			Df			Se			De		
	ADDRESS		Via Molise 4		Registry data			R.C. Corrosion			Cracking pattern			Defect in giuntion and detachment			Component deformation			Settlement			Plaster or finishing decay		
Decision Support System Strategy output					Construction date: 1954		Building Damage Macro Test Criticality	Ox1	Ox2	Ox3	Cr1	Cr2	Cr3	Gi1	Gi2	Gi3	Df1	Df2	Df3	Se1	Se2	Se3	De1	De2	De3
					Total area: 1365 m²																				
					N° of Floors: 2																				
					Construction typology: R.C.																				
					N° of buildings blocks: 2																				
Average Knowledge degree																									
Certified user																									
Max Criticality Condition Rating:																									
Building Condition Rating:																									
2.05																									
Tech. Unit				Element		Sub-element																			
Code	Type	Code	Typology	CCr	Code	Component																			
S	Structural	S1	Foundation	0.65	S1.1	Foundation	2																		
				0.00	S2.1	Shear wall																			
		S2	Structural element	0.65	S2.2	Column	1	1	1																
				1.00	S2.3	Beam	1	2		1															
				0.00	S2.4	Braced frame					1														
L	Load bearing	L1	Slab	1.10	L1.1	Floor slab	1		1		1												4	2	3
				0.00	L1.2	Roof					1														
				0.00	L1.3	Ground floor																			
				0.00	L1.4	Balcony or projection																			
		L2	Connection	0.00	L2.1	Staircase																			
0.00	L2.2			Catwalks																					
N	Non load bearing	N1	Facade envelope	1.00	N1.1	Curtain wall			1														8		
				0.09	N1.2	Windows fixture			1																
				0.00	N1.3	Skylight window																			
		N2	External wall	0.00	N2.1	External R.C. wall																			
				0.00	N2.2	External brick wall																			
				0.00	N2.3	Breastwork																			
		N3	Internal finishes	0.20	N3.1	Internal wall			3															1	
				0.00	N3.2	False ceiling																			
				0.00	N3.3	Door																			
		N4	Other	1.10	N4.1	Joint between elements			4	1	1	1	1											2	
				0.00	N4.1	Elevator																			

CC	BUILDINGS		School Loppolo		MATRIX OF DAMAGE		Cost for repair Test	Ox			Cr			Gi			Df			Se			De																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																	
	ADDRESS		Viale Lazio 8		Registry data			R.C. Corrosion			Cracking pattern			Defect in giuntion and detachment			Component deformation			Settlement			Plaster or finishing decay																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																	
Decision Support System Strategy output					Construction date: 1966		Building Damage Macro Test Criticality	Cracks caused by rebar corrosion			Spalling			Heavy concrete spalling			Thin cracks			Medium cracks			Wide or active cracks			Defects at junction			Detachment of elements			Brick blocks falling down			Component deformation			Excessive deflection or deformations			Walls or elements leaning out of vertical			Small foundation settlement			Medium foundation settlement			Heavy foundation settlement			Decay phenomena (wet area, exfoliation)			Cracking of plaster or veneer			Detachment of plaster or veneer																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																													
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Code	Type	Code	Typology	CCr	Code	Component																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																		

Decision Support System	Survey output	BUILDINGS		Brazilian storage tank		MATRIX OF DAMAGE		Macro Typology	Building Damage	Criticality	Ox			Cr			Gi			Df			Se			De						
		CITY	Fortaleza	Registry data		R.C. Corrosion	Cracking pattern				Defect in giuntion and detachment			Component deformation			Settlement			Plaster or finishing decay												
				Construction period: 1960 - 1980 Total area: 50 m² N° of Floors: 1 Construction typology: R.C. N° of buildings blocks: 1 Average Knowledge degree Certified user Max Criticality Condition Rating: 9.8 Building Condition Rating: 3.05	Code		Component				Ox1	Ox2	Ox3	Cr1	Cr2	Cr3	Gi1	Gi2	Gi3	Df1	Df2	Df3	Se1	Se2	Se3	De1	De2	De3				
Tech. Unit	Code	Type	Code	Typology	CCr	Code	Sub-element																									
S	Structural	S1	Foundation	Structural element	0.00	S1.1	Foundation																									
					0.00	S2.1	Shear wall																									
					3.69	S2.2	Column																									
					9.60	S2.3	Beam																									
					0.00	S2.4	Braced frame																									
L	Load bearing	L1	Slab	Structural element	3.80	L1.1	Floor slab																									
					0.00	L1.2	Roof																									
					0.00	L1.3	Ground floor																									
					0.00	L1.4	Balcony or projection																									
					0.00	L2.1	Staircase																									
N	Non load bearing	N1	Facade envelope	Structural element	0.00	L2.2	Catwalks																									
					0.00	N1.1	Curtain wall																									
					0.00	N1.2	Windows fixture																									
					0.00	N1.3	Skylight window																									
					0.00	N2.1	External R.C. wall																									
		N2	External wall	Structural element	0.00	N2.2	External brick wall																									
					0.00	N2.3	Breastwork																									
					0.00	N3.1	Internal wall																									
		N3	Internal finishes	Structural element	0.00	N3.2	False ceiling																									
					0.00	N3.3	Door																									
		N4	Other	Structural element	0.00	N4.1	Joint between elements Elevator																									

FED	BUILDINGS		Faculdade de Economia		MATRIX OF DAMAGE				Code	Ox			Cr			Gi			Df			Se			De					
	ADDRESS		R. Dr. Roberto Frias 464		Registry data					Max. Criticality	R.C. Corrosion	Cracking pattern		Defect in giuntion and detachment			Component deformation			Settlement			Plaster or finising decay							
Decision Support System		Survey output						Construction period: 1960 - 1980 Total area: 13111 m² Nº of Floors: 3 Construction typology: R.C. Nº of buildings blocks: 3 Average Knowledge degree: Certified user Max Criticality Condition Rating: 9.86 Building Condition Rating: 1.02				Cracks caused by rebar corrosion	Spalling	Heavy concrete spalling	Thin cracks	Medium cracks	Wide or active cracks	Defects at junction	Detachment of elements	Brick blocks falling down	Component deformation	Excessive deflection or deformations	Walls or elements leaning out of vertical	Small foundation settlement	Medium foundation settlement	Heavy foundation settlement	Decay phenomena (wet area, exfoliation)	Cracking of plaster or veneer	Detachment of plaster or veneer	
Tech. Unit	Code	Element	Code	Sub-element	Component	Ox1	Ox2	Ox3	Cr1	Cr2	Cr3																			Gi1
S	Structural	S1	Foundation	0.00	S1.1	Foundation																								
				0.00	S2.1	Shear wall																								
		S2	Structural element	0.19	S2.2	Column		3	16	2		3																		
				0.27	S2.3	Beam					8																	17		
				0.00	S2.4	Braced frame																								
L	Load bearing	L1	Slab		L1.1	Floor slab								1												12		3		
				0.00	L1.2	Roof																								
				0.00	L1.3	Ground floor																								
				2.34	L1.4	Balcony or projection																					70			
				0.09	L2.1	Staircase																					3			
		L2	Connection	0.00	L2.2	Catwalks																								
N	Non load bearing	N1	Facade envelope	0.00	N1.1	Curtain wall																								
				0.00	N1.2	Windows fixture																								
				0.00	N1.3	Skylight window																								
		N2	External wall	1.86	N2.1	External R.C. wall		3	5				14	6	1			2	1							41	2			
				0.00	N2.2	External brick wall																								
				0.00	N2.3	Breastwork																								
		N3	Internal finishes	0.00	N3.1	Internal wall																								
				0.00	N3.2	False ceiling																								
				0.00	N3.3	Door																								
		N4	Other	0.01	N4.1	Joint between elements		3																		6				
				0.00	N4.1	Elevator																								

ATTACHMENTS 3

El Perellonet

CITY		El Perellonet		MATRIX OF DAMAGE		Cod	Ox			Cr			Gi			Df			De																																																																																																																																																																																																																																																																																																																																																																																							
ADDRESS				Registry data			R.C. Corrosion			Cracking pattern			Defect in giuntion and detachment			Component deformation			Plaster or finishing decay																																																																																																																																																																																																																																																																																																																																																																																							
Decision Support System	Survey output			Total area: 2400 m²		Building Damage	Macro type	Cod	Ox1	Ox2	Ox3	Cr1	Cr2	Cr3	Gi1	Gi2	Gi3	Df1	Df2	Df3	De1	De2	De3																																																																																																																																																																																																																																																																																																																																																																																			
				Nº of Floors: 6																																																																																																																																																																																																																																																																																																																																																																																																						
				Area of single floor: 400 m²																																																																																																																																																																																																																																																																																																																																																																																																						
				Construction typology: R.C.																																																																																																																																																																																																																																																																																																																																																																																																						
				Nº of buildings blocks: 1																																																																																																																																																																																																																																																																																																																																																																																																						
Building Condition Rating:		4.9																																																																																																																																																																																																																																																																																																																																																																																																								
Tech. Unit		Element		Sub-element																																																																																																																																																																																																																																																																																																																																																																																																						
Code	Type	Code	Typology	CCr	Code	Component	Cracks caused by rebar corrosion		Spalling		Heavy concrete spalling		Thin cracks		Medium cracks		Wide or active cracks		Defects at junction		Detachment of elements		Brick blocks falling down		Component deformation		Excessive deflection or deformations		Walls or elements leaning out of vertical		Decay phenomena (wet area, exfoliation)		Cracking of plaster or veneer		Detachment of plaster or veneer																																																																																																																																																																																																																																																																																																																																																																							
S	Str.	S2	Structural element	1.20	S2.2	Column						14									14																																																																																																																																																																																																																																																																																																																																																																																					
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L	Load b.	L1	Slab	4.90	L1.4	Balcony or projection						30																																																																																																																																																																																																																																																																																																																																																																																														

P2	CITY		El Perellonet		MATRIX OF DAMAGE		Cod	Ox			Cr			Gi			Df			De			
	ADDRESS		Calle de la Escotilla		Registry data			R.C. Corrosion			Cracking pattern			Defect in giuntion and detachment			Component deformation			Plaster or finishing decay			
					Total area: 2400 m²			Ox1			Cr1			Gi1			Df1			De1			
					Nº of Floors: 6			Ox2			Cr2			Gi2			Df2			De2			
Decision Support System	Survey output					Area of single floor: 400 m²		Building Damages	Cracks caused by rebar corrosion			Thin cracks			Defects at junction			Component deformation			Decay phenomena (wet area, exfoliation)		
						Construction typology: R.C.			Spalling			Medium cracks			Detachment of elements			Excessive deflection or deformations			Cracking of plaster or veneer		
						Nº of buildings blocks: 1			Heavy concrete spalling			Wide or active cracks			Brick blocks falling down			Walls or elements leaning out of vertical			Detachment of plaster or veneer		
						Building Condition Rating:																	
Tech. Unit		Element		Sub-element																			
Code	Type	Code	Typology	CCr	Code	Component																	
S	Str.	S2	Structural element	0.00	S2.2	Column																	
				0.00	S2.3																		
L	Load b.	L1	Slab	5.09	L1.4	Balcony or projection																	
		L2	Connection	0.00	L2.1														21	31			
N	Non load bearing	N1	Facade envelope	0.00	N1.1	Curtain wall																	
				0.00	N1.2	Windows fixture																	
		N2	External wall	0.00	N2.1	External R.C. wall																	
				0.00	N2.2	External brick wall																	
		N4	Other	0.00	N4.1	Joint between elements																	

P3	CITY		El Perellonet		MATRIX OF DAMAGE			Cod	Ox			Cr			Gi			Df			De		
	ADDRESS		Paseo de las golas		Registry data				R.C. Corrosion			Cracking pattern			Defect in giuntion and detachment			Component deformation			Plaster or finishing decay		
			Total area: 2280 m²			Ox1			Cr1			Gi1			Df1			De1					
			Nº of Floors: 6			Ox2			Cr2			Gi2			Df2			De2					
Decision Support System	Survey output			Area of single floor: 380 m²			Building Damages	Cracks caused by rebar corrosion			Thin cracks			Defects at junction			Component deformation			Decay phenomena (wet area, exfoliation)			
				Construction typology: R.C.				Spalling			Medium cracks			Detachment of elements			Excessive deflection or deformations			Cracking of plaster or veneer			
				Nº of buildings blocks: 1				Heavy concrete spalling			Wide or active cracks			Brick blocks falling down			Walls or elements leaning out of vertical			Detachment of plaster or veneer			
				Building Condition Rating:																			
Tech. Unit		Element		Sub-element																			
Code	Type	Code	Typology	CCr	Code	Component																	
S	Str.	S2	Structural element	1.30	S2.2	Column	18				2												
				0.60	S2.3	Beam	5			1													
				3.09	L1.4	Balcony or projection	3		1												7		
L	Load b.	L1	Slab	0.00	L1.1															14			
		L2	Connection	0.00	L2.1	Staircase																	
N	Non load bearing	N1	Facade envelope	0.20	N1.1	Curtain wall														4			
				0.00	N1.2	Windows fixture																	
				0.00	N2.1	External R.C. wall																	
				0.00	N2.2	External brick wall																	
				0.00	N4.1	Joint between elements																	
		N4	Other	0.00																			

P4	CITY		El Perellonet		MATRIX OF DAMAGE		Cod	Ox			Cr			Gi			Df			De																								
	ADDRESS		Paseo de las golas		Registry data			R.C. Corrosion			Cracking pattern			Defect in giuntion and detachment			Component deformation			Plaster or finiscing decay																								
					Total area: 4640 m ² Nº of Floors: 8 Area of single floor: 580 m ² Construction typology: R.C. Nº of buildings blocks: 2 Building Condition Rating: 0.18			Ox1 Ox2 Ox3			Cr1 Cr2 Cr3			Gi1 Gi2 Gi3			Df1 Df2 Df3			De1 De2 De3																								
								Cracks caused by rebar corrosion			Spalling			Heavy concrete spalling			Thin cracks			Medium cracks			Wide or active cracks			Defects at junction			Detachment of elements			Brick blocks falling down			Component deformation			Excessive deflection or deformations			Walls or elements leaning out of vertical			Decay phenomena (wet area, exfoliation)
Tech. Unit		Element		Sub-element																																								
Code	Type	Code	Typology	CCr	Code	Component																																						
S	Str.	S2	Structural element	0.00	S2.2	Column																																						
				0.00	S2.3	Beam																																						
L	Load b.	L1	Slab	0.35	L1.4	Balcony or projection															10																							
		L2	Connection	0.00	L2.1	Staircase																																						
N	Non load bearing	N1	Facade envelope	0.00	N1.1	Curtain wall																																						
				0.00	N1.2	Windows fixture																																						
		N2	External wall	0.00	N2.1	External R.C. wall																																						
				0.00	N2.2	External brick wall																																						
		N4	Other	0.00	N4.1	Joint between elements																																						

P5	CITY		El Perellonet		MATRIX OF DAMAGE		Cod	Ox			Cr			Gi			Df			De																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																				
	ADDRESS		Paseo de las golas		Registry data			R.C. Corrosion			Cracking pattern			Defect in giuntion and detachment			Component deformation			Plaster or finiscing decay																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																				
					Total area: 5580 m ²			Cracks caused by rebar corrosion			Spalling			Heavy concrete spalling			Thin cracks			Medium cracks			Wide or active cracks			Defects at junction			Detachment of elements			Brick blocks falling down			Component deformation			Excessive deflection or deformations			Walls or elements leaning out of vertical			Decay phenomena (wet area, exfoliation)			Cracking of plaster or veneer			Detachment of plaster or veneer																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																						
					Nº of Floors: 9																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																			
					Area of single floor: 620 m ²																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																			
Construction typology: R.C.																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																								
				Nº of buildings blocks: 3																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																				

P6	CITY		El Perellonet		MATRIX OF DAMAGE		Cod	Ox			Cr			Gi			Df			De																								
	ADDRESS		Av de las Gaviota		Registry data			R.C. Corrosion			Cracking pattern			Defect in giuntion and detachment			Component deformation			Plaster or finiscing decay																								
					Total area: 6888 m ² Nº of Floors: 12 Area of single floor: 574 m ² Construction typology: R.C. Nº of buildings blocks: 4 Building Condition Rating: 0.42			Ox1 Ox2 Ox3			Cr1 Cr2 Cr3			Gi1 Gi2 Gi3			Df1 Df2 Df3			De1 De2 De3																								
								Cracks caused by rebar corrosion			Spalling			Heavy concrete spalling			Thin cracks			Medium cracks			Wide or active cracks			Defects at junction			Detachment of elements			Brick blocks falling down			Component deformation			Excessive deflection or deformations			Walls or elements leaning out of vertical			Decay phenomena (wet area, exfoliation)
Tech. Unit		Element		Sub-element																																								
Code	Type	Code	Typology	CCr	Code	Component																																						
S	Str.	S2	Structural element	0.00	S2.2	Column																																						
				0.00	S2.3	Beam																																						
L	Load b.	L1	Slab	0.84	L1.4	Balcony or projection															30																							
		L2	Connection	0.00	L2.1	Staircase																																						
N	Non load bearing	N1	Facade envelope	0.00	N1.1	Curtain wall																																						
				0.00	N1.2	Windows fixture																																						
		N2	External wall	0.00	N2.1	External R.C. wall																																						
				0.00	N2.2	External brick wall																																						
		N4	Other	0.00	N4.1	Joint between elements																																						

Pt	CITY		El Perdonet		MATRIX OF DAMAGE		Cod	Ox			Cr			Gi			Df			De		
	ADDRESS		Av de las Gaviota		Registry data			R.C. Corrosion			Cracking pattern			Defect in giuntion and detachment			Component deformation			Plaster or finiscing decay		
Decision Support System Survey output					Total area: 3300 m ² N° of Floors: 11 Area of single floor: 300 m ² Construction typology: R.C. N° of buildings blocks: 1 Building Condition Rating: 1.08		Building Damage Criticality	Macro Type			Micro Type			Macro Type			Micro Type			Macro Type		
								Cracks caused by rebar corrosion			Cracks caused by rebar corrosion			Cracks caused by rebar corrosion			Cracks caused by rebar corrosion			Cracks caused by rebar corrosion		
								Spalling			Spalling			Spalling			Spalling			Spalling		
								Heavy concrete spalling			Heavy concrete spalling			Heavy concrete spalling			Heavy concrete spalling			Heavy concrete spalling		
								Thin cracks			Thin cracks			Thin cracks			Thin cracks			Thin cracks		
Tech. Unit		Element		Sub-element																		
Code	Type	Code	Typology	CCr	Code	Component																
S	Str	S2	Structural element	0.00	S2.2	Column																
				0.00	S2.3	Beam																
L	Load b.	L1	Slab	1.17	L1.4	Balcony or projection																
				0.00	L2.1	Staircase																
N	Non load bearing	N1	Facade envelope	0.34	N1.1	Curtain wall																
				0.00	N1.2	Windows fixture																
		N2	External wall	0.00	N2.1	External R.C. wall																
				0.00	N2.2	External brick wall																
		N4	Other	0.00	N4.1	Joint between elements																

P#	CITY ADDRESS		El Perdonet Calle de Estribor		MATRIX OF DAMAGE		Code	Ox			Cr			Gi			Df			De																													
					Registry data		Macro Type	R.C. Corrosion			Cracking pattern			Defect in giuntion and detachment			Component deformation			Plaster or finiscing decay																													
Decision Support System Survey output					Total area: 1200 m ² N° of Floors: 4 Area of single floor: 300 m ² Construction typology: R.C. N° of buildings blocks: 1 Building Condition Rating: 1.26		Building Damage Criticality	Cracks caused by rebar corrosion			Cracking pattern			Defects at junction			Component deformation			Plaster or finiscing decay																													
								Code	Ox1	Ox2	Ox3	Cr1	Cr2	Cr3	Gi1	Gi2	Gi3	Df1	Df2	Df3	De1	De2	De3																										
								Spalling			Heavy concrete spalling			Thin cracks			Medium cracks			Wide or active cracks			Detectors at junction			Detachment of elements			Brick blocks falling down			Component deformation			Excessive deflection or deformations			Walls or elements leaning out of vertical			Decay phenomena (wet area, exfoliation)			Cracking of plaster or veneer			Detachment of plaster or veneer		
Tech. Unit		Element		Sub-element																																													
Code	Type	Code	Typology	CCr	Code	Component																																											
S	Str.	S2	Structural element	0.39 0.00	S2.2 S2.3	Column Beam			1																																								
L	Load b.	L1	Slab	1.34 0.00	L1.4 L2.1	Balcony or projection Staircase			3												3																												
N	Non load bearing	N1	Facade envelope	0.00 0.00	N1.1 N1.2	Curtain wall Windows fixture																																											
		N2	External wall	0.00 0.00	N2.1 N2.2	External R.C. wall External brick wall																																											
		N4	Other	0.00	N4.1	Joint between elements																																											

Pp	CITY	El Perdonet	MATRIX OF DAMAGE			Code	Ox			Cr			Gi			Df			De		
Decision Support System Survey output	ADDRESS	Calle de Estribor	Registry data			Macro Type	R.C. Corrosion			Cracking pattern			Defect in giuntion and detachment			Component deformation			Plaster or finiscing decay		
			Total area: m²			Building Damages Critically	Ox1	Ox2	Ox3	Cr1	Cr2	Cr3	Gi1	Gi2	Gi3	Df1	Df2	Df3	De1	De2	De3
			Nº of Floors:				Cracks caused by rebar corrosion			Cracking pattern			Defects at junction			Component deformation			Plaster or finiscing decay		
			Area of single floor: m²				Spalling		Heavy concrete spalling	Thin cracks	Medium cracks	Wide or active cracks	Defects at junction	Detachment of elements	Brick blocks falling down	Component deformation	Excessive deflection or deformations	Walls or elements leaning out of vertical	Decay phenomena (wet area, exfoliation)	Cracking of plaster or veneer	Detachment of plaster or veneer
			Construction typology: R.C.																		
			Nº of buildings blocks: 1																		
Building Condition Rating:																					
8.12																					
Tech. Unit		Element		Sub-element																	
Code	Type	Code	Typology	CCr	Code	Component															
S	Str.	S2	Structural element	2.01	S2.2	Column															
				0.00	S2.3	Beam															
L	Load b.	L1	Slab	1.38	L1.1																
				1.03	L1.4	Balcony or projection															
N	Non load bearing	N1	Facade envelope	1.04	N1.1	Curtain wall															
				0.07	N1.2	Windows fixture															
		N2	External wall	0.00	N2.1	External R.C. wall															
				0.00	N2.2	External brick wall															
		N4	Other	0.00	N4.1	Joint between elements															

[illegible]

P13	CITY		El Perellonet		MATRIX OF DAMAGE		Macro Type	Ox			Cr			Gi			Df			De				
	ADDRESS		Entrada Llobarro		Registry data			R.C. Corrosion			Cracking pattern			Defect in giuntion and detachment			Component deformation			Plaster or finiscing decay				
					Total area: 10140 m² Nº of Floors: 10 Area of single floor: 1690 m² Construction typology: R.C. Nº of buildings blocks: 4 Building Condition Rating: 0.51			Cracks caused by rebar corrosion			Spalling			Thin cracks			Defects at junction			Decay phenomena (wet area, exfoliation)				
								Ox1	Ox2	Ox3	Cr1	Cr2	Cr3	Gi1	Gi2	Gi3	Df1	Df2	Df3	De1	De2	De3		
Tech. Unit		Element			Sub-element		Building Damage	Cracks caused by rebar corrosion			Spalling			Thin cracks			Defects at junction			Decay phenomena (wet area, exfoliation)				
Code	Type	Code	Typology	CCr	Code	Component		Cracks caused by rebar corrosion			Spalling			Thin cracks			Defects at junction			Decay phenomena (wet area, exfoliation)				
S	Str.	S2	Structural element	0.06	S2.2	Column		9																
				0.14	S2.3	Beam		8	2											5				
L	Load b.	L1	Slab	0.15	L1.1	Slab																		
				0.00	L1.4	Balcony or projection		15																
N	Non load bearing	N1	Facade envelope	0.02	N1.1	Curtain wall		2																
				0.00	N1.2	Windows fixture																		
		N2	External wall	0.00	N2.1	External R.C. wall																		
				0.00	N2.2	External brick wall																		
		N4	Other	0.00	N4.1	Joint between elements																		
				0.00																				

P14	CITY		El Perellonet		MATRIX OF DAMAGE		Macro Type	Ox			Cr			Gi			Df			De		
	ADDRESS		Entrada Llobarro		Registry data			R.C. Corrosion			Cracking pattern			Defect in giuntion and detachment			Component deformation			Plaster or finising decay		
					Total area: 5200 m² Nº of Floors: 4 Area of single floor: 1300 m² Construction typology: R.C. Nº of buildings blocks: 5 Building Condition Rating:			Cracks caused by rebar corrosion			Spalling			Thin cracks			Defects at junction			Decay phenomena (wet area, exfoliation)		
								Ox1	Ox2	Ox3	Cr1	Cr2	Cr3	Gi1	Gi2	Gi3	Df1	Df2	Df3	De1	De2	De3
Tech. Unit		Element			Sub-element		Building Damage	Cracks caused by rebar corrosion			Spalling			Thin cracks			Defects at junction			Decay phenomena (wet area, exfoliation)		
Code	Type	Code	Typology	CCr	Code	Component		Cracks caused by rebar corrosion			Spalling			Thin cracks			Defects at junction			Decay phenomena (wet area, exfoliation)		
S	Str.	S2	Structural element	0.23	S2.2	Column		12														
				0.11	S2.3	Beam		6														
L	Load b.	L1	Slab	0.34	L1.4	Balcony or projection														9		
				0.00	L2.1	Staircase																
N	Non load bearing	N1	Facade envelope	0.05	N1.1	Curtain wall														6		
				0.00	N1.2	Windows fixture																
		N2	External wall	0.00	N2.1	External R.C. wall																
				0.00	N2.2	External brick wall																
		N4	Other	0.00	N4.1	Joint between elements																
				0.00																		

P15	CITY		El Perellonet		MATRIX OF DAMAGE		Macro Type	Ox			Cr			Gi			Df			De		
	ADDRESS		Av de las Gaviota		Registry data			R.C. Corrosion			Cracking pattern			Defect in giuntion and detachment			Component deformation			Plaster or finiscing decay		
					Total area: 5500 m²			Cracks caused by rebar corrosion			Spalling			Thin cracks			Defects at junction			Decay phenomena (wet area, exfoliation)		
					Nº of Floors: 5																	
					Area of single floor: 1100 m²																	
				Construction typology: R.C.																		
				Nº of buildings blocks: 2																		
				Building Condition Rating:																		
				0.79																		
Tech. Unit		Element			Sub-element																	
Code	Type	Code	Typology	CCr	Code	Component																
S	Str.	S2	Structural element	0.10	S2.2	Column																
				0.10	S2.3	Beam																
L	Load b.	L1	Slab	0.59	L1.4	Balcony or projection																
				0.00	L2.1	Staircase																
N	Non load bearing	N1	Facade envelope	0.09	N1.1	Curtain wall																
				0.00	N1.2	Windows fixture																
		N2	External wall	0.00	N2.1	External R.C. wall																
				0.00	N2.2	External brick wall																
		N4	Other	0.00	N4.1	Joint between elements																

[illegible]

P-19	CITY		El Perellonet		MATRIX OF DAMAGE		Csd	Ox			Cr			Gi			Df			De																																		
	ADDRESS		Calle de Galfins		Registry data			R.C. Corrosion			Cracking pattern			Defect in giuntion and detachment			Component deformation			Plaster or finiscing decay																																		
Decision Support System Survey output					Total area: 16500 m ²		Building Damage	Macro Type	Criticality	Cracks caused by rebar corrosion			Spalling			Heavy concrete spalling			Thin cracks			Medium cracks			Wide or active cracks			Defects at junction			Detachment of elements			Brick blocks falling down			Component deformation			Excessive deflection or deformations			Walls or elements leaning out of vertical			Decay phenomena (wet area, exfoliation)			Cracking of plaster or veneer			Detachment of plaster or veneer		
Area of single floor: 1100 m ²		Cracks caused by rebar corrosion			Spalling			Thin cracks			Medium cracks			Wide or active cracks			Defects at junction			Detachment of elements			Brick blocks falling down			Component deformation			Excessive deflection or deformations			Walls or elements leaning out of vertical			Decay phenomena (wet area, exfoliation)			Cracking of plaster or veneer			Detachment of plaster or veneer													
Construction typology: R.C.		Cracks caused by rebar corrosion			Spalling			Thin cracks			Medium cracks			Wide or active cracks			Defects at junction			Detachment of elements			Brick blocks falling down			Component deformation			Excessive deflection or deformations			Walls or elements leaning out of vertical			Decay phenomena (wet area, exfoliation)			Cracking of plaster or veneer			Detachment of plaster or veneer													
N° of buildings blocks: 5		Cracks caused by rebar corrosion			Spalling			Thin cracks			Medium cracks			Wide or active cracks			Defects at junction			Detachment of elements			Brick blocks falling down			Component deformation			Excessive deflection or deformations			Walls or elements leaning out of vertical			Decay phenomena (wet area, exfoliation)			Cracking of plaster or veneer			Detachment of plaster or veneer													
Building Condition Rating:		Cracks caused by rebar corrosion			Spalling			Thin cracks			Medium cracks			Wide or active cracks			Defects at junction			Detachment of elements			Brick blocks falling down			Component deformation			Excessive deflection or deformations			Walls or elements leaning out of vertical			Decay phenomena (wet area, exfoliation)			Cracking of plaster or veneer			Detachment of plaster or veneer													
0.49		Cracks caused by rebar corrosion			Spalling			Thin cracks			Medium cracks			Wide or active cracks			Defects at junction			Detachment of elements			Brick blocks falling down			Component deformation			Excessive deflection or deformations			Walls or elements leaning out of vertical			Decay phenomena (wet area, exfoliation)			Cracking of plaster or veneer			Detachment of plaster or veneer													
Tech. Unit		Element			Sub-element		Building Damage		Cracks caused by rebar corrosion			Spalling			Thin cracks			Medium cracks			Wide or active cracks			Defects at junction			Detachment of elements			Brick blocks falling down			Component deformation			Excessive deflection or deformations			Walls or elements leaning out of vertical			Decay phenomena (wet area, exfoliation)			Cracking of plaster or veneer			Detachment of plaster or veneer						
Code	Type	Code	Typology	CCr	Code	Component	Macro	Micro	Cracks caused by rebar corrosion			Spalling			Thin cracks			Medium cracks			Wide or active cracks			Defects at junction			Detachment of elements			Brick blocks falling down			Component deformation			Excessive deflection or deformations			Walls or elements leaning out of vertical			Decay phenomena (wet area, exfoliation)			Cracking of plaster or veneer			Detachment of plaster or veneer						
S	Str.	S2	Structural element	0.08	S2.2	Column	Building Damage	Criticality	12			Spalling			Thin cracks			Medium cracks			Wide or active cracks			Defects at junction			Detachment of elements			Brick blocks falling down			Component deformation			Excessive deflection or deformations			Walls or elements leaning out of vertical			Decay phenomena (wet area, exfoliation)			Cracking of plaster or veneer			Detachment of plaster or veneer						
				0.09	S2.3	Beam			16																																													
L	Load b.	L1	Slab	0.35	L1.4	Balcony or projection	Building Damage	Criticality																																														
				0.00	L2.1	Staircase																																																
N	Non load bearing	N1	Facade envelope	0.04	N1.1	Curtain wall	Building Damage	Criticality																																														
				0.00	N1.2	Windows fixture																																																
		N2	External wall	0.00	N2.1	External R.C. wall																																																
				0.00	N2.2	External brick wall																																																
		N4	Other	0.00	N4.1	Joint between elements																																																

P-20	CITY		El Perellonet		MATRIX OF DAMAGE		Csd	Ox			Cr			Gi			Df			De			
	ADDRESS		Av de las Gaviota		Registry data			R.C. Corrosion			Cracking pattern			Defect in giuntion and detachment			Component deformation			Plaster or finiscing decay			
					Total area: 3960 m ²			Cracks caused by rebar corrosion			Spalling			Detachment of elements			Component deformation			Deterioration of plaster or veneer			
					N° of Floors: 6			Cracks caused by rebar corrosion			Spalling			Detachment of elements			Component deformation			Deterioration of plaster or veneer			
Area of single floor: 660 m ²					Cracks caused by rebar corrosion			Spalling			Detachment of elements			Component deformation			Deterioration of plaster or veneer						
Construction typology: R.C.		N° of buildings blocks: 1		Building Condition Rating:		Cracks caused by rebar corrosion			Spalling			Detachment of elements			Component deformation			Deterioration of plaster or veneer					
Building Condition Rating:		1.32				Cracks caused by rebar corrosion			Spalling			Detachment of elements			Component deformation			Deterioration of plaster or veneer					
Tech. Unit		Element		Sub-element		Building Damage		Cracks caused by rebar corrosion			Spalling			Detachment of elements			Component deformation			Deterioration of plaster or veneer			
Code	Type	Code	Typology	CCr	Code	Component	Macro	Micro	Cracks caused by rebar corrosion			Spalling			Detachment of elements			Component deformation			Deterioration of plaster or veneer		
S	Str.	S2	Structural element	0.15	S2.2	Column	Building Damage	Criticality	5												1		
				0.36	S2.3	Beam			10												4		
L	Load b.	L1	Slab	0.03	L1.1	Slab	Building Damage	Criticality													1		
				0.40	L1.4	Balcony or projection															5		
N	Non load bearing	N1	Facade envelope	0.02	N1.1	Curtain wall	Building Damage	Criticality													3		
				0.26	N1.2	Windows fixture									5								
		N2	External wall	0.00	N2.1	External R.C. wall																	
				0.00	N2.2	External brick wall																	
		N4	Other	0.00	N4.1	Joint between elements																	

P-21	CITY		El Perellonet		MATRIX OF DAMAGE		Csd	Ox			Cr			Gi			Df			De			
	ADDRESS		Av. Gaviotas		Registry data			R.C. Corrosion			Cracking pattern			Defect in giuntion and detachment			Component deformation			Plaster or finiscing decay			
					Total area: 5700 m ²			Cracks caused by rebar corrosion			Spalling			Detachment of elements			Component deformation			Deterioration of plaster or veneer			
					N° of Floors: 20			Spalling			Detachment of elements			Component deformation			Deterioration of plaster or veneer						
Tech. Unit		Element			Sub-element		Building Damage		Cracks caused by rebar corrosion			Spalling			Detachment of elements			Component deformation			Deterioration of plaster or veneer		
Code	Type	Code	Typology	CCr	Code	Component	Macro	Micro	Cracks caused by rebar corrosion			Spalling			Detachment of elements			Component deformation			Deterioration of plaster or veneer		
S	Str.	S2	Structural element	0.00	S2.2	Column	Building Damage	Criticality															
				0.14	S2.3	Beam												4					
L	Load b.	L1	Slab	3.40	L1.4	Balcony or projection	Building Damage	Criticality				20									20		
				0.00	L2.1	Staircase																	
N	Non load bearing	N1	Facade envelope	0.12	N1.1	Curtain wall	Building Damage	Criticality													16		
				0.00	N1.2	Windows fixture																	
		N2	External wall	0.00	N2.1	External R.C. wall																	
				0.00	N2.2	External brick wall																	
		N4	Other	0.00	N4.1	Joint between elements																	

P22	CITY		El Perellonet		MATRIX OF DAMAGE		Cod	Ox			Cr			Gi			Df			De																													
	ADDRESS		Av. Gaviotas		Registry data			R.C. Corrosion			Cracking pattern			Defect in giuntion and detachment			Component deformation			Plaster or finiscing decay																													
					Total area: 3600 m ²			Cracks caused by rebar corrosion			Spalling			Thin cracks			Medium cracks			Wide or active cracks			Defects at junction			Detachment of elements			Brick blocks falling down			Component deformation			Excessive deflection or deformations			Walls or elements leaning out of vertical			Decay phenomena (wet area, exfoliation)			Cracking of plaster or veneer			Detachment of plaster or veneer		
					Nº of Floors: 12																																												
					Area of single floor: 300 m ²																																												
					Construction typology: R.C.																																												
					Nº of buildings blocks: 2																																												
	Building Condition Rating:																																																
	0.2																																																
	Tech. Unit		Element		Sub-element																																												
Code	Type	Code	Typology	CCr	Code	Component																																											
S	Str.	S2	Structural element	0.01 0.01	S2.2 S2.3	Column Beam	1														1																												
L	Load b.	L1	Slab	0.01	L1.4	Balcony or projection															2																												
		L2	Connection	0.00	L2.1	Staircase																																											
N	Non load bearing	N1	Facade envelope	0.01 0.00	N1.1 N1.2	Curtain wall Windows fixture															2																												
		N2	External wall	0.00 0.00	N2.1 N2.2	External R.C. wall External brick wall																																											
		N4	Other	0.00	N4.1	Joint between elements																																											

Decision Support System		P25		CITY	El Perellonet		MATRIX OF DAMAGE			Cod	Ox			Cr			Gi			Df			De																								
				ADDRESS	Calle de la Sirena		Registry data				R.C. Corrosion			Cracking pattern			Defect in giuntion and detachment			Component deformation			Plaster or finishing decay																								
						Total area: 7810 m ²			Building Damage																																						
						Nº of Floors: 8																																									
						Area of single floor: 710 m ²																																									
						Construction typology: R.C.																																									
						Nº of buildings blocks: 4																																									
						Building Condition Rating:																																									
						0.49																																									
Tech. Unit		Element			Sub-element			Criticality	Cracks caused by rebar corrosion			Thin cracks			Medium cracks			Wide or active cracks			Defects at junction			Detachment of elements			Brick blocks falling down			Component deformation			Excessive deflection or deformations			Walls or elements leaning out of vertical			Decay phenomena (wet area, exfoliation)			Cracking of plaster or veneer			Detachment of plaster or veneer		
Code	Type	Code	Typology	CCr	Code	Component	Spalling			Heavy concrete spalling																																					
S	Str.	S2	Structural element	0.14	S2.2	Column																																									
				0.02	S2.3	Beam																																									
L	Load b.	L1	Slab	0.29	L1.4	Balcony or projection																																									
				0.00	L2.1	Staircase																																									
N	Non load bearing	N1	Facade envelope	0.05	N1.1	Curtain wall																																									
				0.00	N1.2	Windows fixture																																									
		N2	External wall	0.00	N2.1	External R.C. wall																																									
				0.00	N2.2	External brick wall																																									
		N4	Other	0.00	N4.1	Joint between elements																																									

P26	CITY		El Perellonet		MATRIX OF DAMAGE			Cod	Ox			Cr			Gi			Df			De		
	ADDRESS		Calle de la Sirena		Registry data				R.C. Corrosion			Cracking pattern			Defect in giuntion and detachment			Component deformation			Plaster or finishing decay		
			Total area: 7200 m²			Ox1			Cr1			Gi1			Df1			De1					
			Nº of Floors: 15			Ox2			Cr2			Gi2			Df2			De2					
Decision Support System	Survey output	Area of single floor: 480 m²			Construction typology: R.C.			Building Damages	Cracks caused by rebar corrosion			Thin cracks			Defects at junction			Component deformation			Decay phenomena (wet area, exfoliation)		
		Nº of buildings blocks: 2			Ox3				Spalling			Medium cracks			Detachment of elements			Excessive deflection or deformations			Cracking of plaster or veneer		
		Building Condition Rating:			Heavy concrete spalling							Brick blocks falling down			Walls or elements leaning out of vertical			Detachment of plaster or veneer					
6.7																							
Tech. Unit		Element			Sub-element			Criticality															
Code	Type	Code	Typology	CCr	Code	Component	Cracks caused by rebar corrosion			Thin cracks			Defects at junction			Component deformation			Decay phenomena (wet area, exfoliation)				
S	Str.	S2	Structural element	1.14	S2.2	Column													6				
				0.86	S2.3	Beam													20				
L	Load b.	L1	Slab	1.28	L1.4	Balcony or projection	59												59				
				0.00	L2.1	Staircase																	
N	Non load bearing	N1	Facade envelope	1.28	N1.1	Curtain wall													48				
				0.00	N1.2	Windows fixture																	
		N2	External wall	0.00	N2.1	External R.C. wall																	
				0.00	N2.2	External brick wall																	
		N4	Other	0.00	N4.1	Joint between elements																	

P27	CITY		El Perellonet		MATRIX OF DAMAGE		Cod	Ox			Cr			Gi			Df			De				
	ADDRESS		Calle de la Sirena		Registry data			R.C. Corrosion			Cracking pattern			Defect in giuntion and detachment			Component deformation			Plaster or finishing decay				
					Total area: 12600 m ²			Ox1			Cr1			Gi1			Df1			De1				
					Nº of Floors: 7			Ox2			Cr2			Gi2			Df2			De2				
Decision Support System		Survey output						Area of single floor: 1800 m ²		Spalling			Thin cracks			Defects at junction			Component deformation			Decay phenomena (wet area, exfoliation)		
		Construction typology: R.C.						Heavy concrete spalling			Medium cracks			Detachment of elements			Excessive deflection or deformations			Cracking of plaster or veneer				
		Nº of buildings blocks: 4									Wide or active cracks			Brick blocks falling down			Walls or elements leaning out of vertical			Detachment of plaster or veneer				
				Building Condition Rating:																				
				3.2																				
Tech. Unit		Element		Sub-element		Criticality		Cracks caused by rebar corrosion			Thin cracks			Defects at junction			Component deformation			Decay phenomena (wet area, exfoliation)				
Code	Type	Code	Typology	CCr	Code	Component		Corrosion	Spalling	Heavy concrete spalling	Thin cracks	Medium cracks	Wide or active cracks	Defects at junction	Detachment of elements	Brick blocks falling down	Component deformation	Excessive deflection or deformations	Walls or elements leaning out of vertical	Decay phenomena (wet area, exfoliation)				
S	Str.	S2	Structural element	0.49	S2.2	Column		45																
				0.55	S2.3	Beam		16												32				
L	Load b.	L1	Slab	0.60	L1.4	Balcony or projection		8												24				
		L2	Connection	0.00	L2.1	Staircase																		
N	Non load bearing	N1	Facade envelope	0.90	N1.1	Curtain wall					30									30				
				0.00	N1.2	Windows fixture																		
		N2	External wall	0.00	N2.1	External R.C. wall																		
				0.00	N2.2	External brick wall																		
		N4	Other	0.00	N4.1	Joint between elements														30				

P28	CITY		El Perellonet		MATRIX OF DAMAGE		Cod	Ox			Cr			Gi			Df			De																																	
	ADDRESS		Paseo de las Golas		Registry data			R.C. Corrosion			Cracking pattern			Defect in giuntion and detachment			Component deformation			Plaster or finiscing decay																																	
			Total area: 990 m ²		Master Type Criticality Building Damage			Cracks caused by rebar corrosion			Spalling			Heavy concrete spalling			Thin cracks			Medium cracks			Wide or active cracks			Defects at junction			Detachment of elements			Brick blocks falling down			Component deformation			Excessive deflection or deformations			Walls or elements leaning out of vertical			Decay phenomena (wet area, exfoliation)			Cracking of plaster or veneer			Detachment of plaster or veneer			
			Nº of Floors: 5																																																		
			Area of single floor: 198 m ²																																																		
			Construction typology: R.C.																																																		
Nº of buildings blocks: 1																																																					
Building Condition Rating:		5.8																																																			
Tech. Unit		Element				Sub-element																																															
Code	Type	Code	Typology	CCr	Code	Component																																															
S	Str.	S2	Structural element	0.56	S2.2	Column																																															
				2.89	S2.3	Beam	20																																														
L	Load b.	L1	Slab	0.00	L1.4	Balcony or projection																																															
		L2	Connection	0.00	L2.1	Staircase																																															
N	Non load bearing	N1	Facade envelope	0.45	N1.1	Curtain wall																																															
				0.00	N1.2	Windows fixture																																															
				0.00	N2.1	External R.C. wall																																															
		N2	External wall	0.00	N2.2	External brick wall																																															
				0.00	N4.1	Joint between elements																																															

P29	CITY		El Perellonet		MATRIX OF DAMAGE		Cod	Ox			Cr			Gi			Df			De			
	ADDRESS		Av de las Gaviotas		Registry data			R.C. Corrosion			Cracking pattern			Defect in giuntion and detachment			Component deformation			Plaster or finiscing decay			
			Total area: 5200 m² Nº of Floors: 5 Area of single floor: 1040 m² Construction typology: R.C. Nº of buildings blocks: 5 Building Condition Rating: 8.5		Cracks caused by rebar corrosion	Spalling		Heavy concrete spalling	Thin cracks	Medium cracks	Wide or active cracks	Defects at junction	Detachment of elements	Brick blocks falling down	Component deformation	Excessive deflection or deformations	Walls or elements leaning out of vertical	Decay phenomena (wet area, exfoliation)	Cracking of plaster or veneer	Detachment of plaster or veneer			
Tech. Unit		Element		Sub-element		Macro Type	Criticality																
Code	Type	Code	Typology	CCr	Code			Component															
S	Str.	S2	Structural element	0.64	S2.2			Column															
				2.29	S2.3			Beam	126														
L	Load b.	L1	Slab	0.78	L1.4	Balcony or projection	45																
		L2	Connection	0.00	L2.1	Staircase																	
N	Non load bearing	N1	Facade envelope	0.13	N1.1	Curtain wall																	
				0.00	N1.2	Windows fixture																	
				0.00	N2.1	External R.C. wall																	
		N2	External wall	0.00	N2.2	External brick wall																	
				0.00	N4.1	Joint between elements																	

P30	CITY		El Perellonet		MATRIX OF DAMAGE		Cod	Ox			Cr			Gi			Df			De			
	ADDRESS		Av de las Gaviotas		Registry data			R.C. Corrosion			Cracking pattern			Defect in giuntion and detachment			Component deformation			Plaster or finiscing decay			
			Total area: 23178 m²		Building Damage Criticality			Cracks caused by rebar corrosion Spalling Heavy concrete spalling			Thin cracks Medium cracks Wide or active cracks			Defects at junction Detachment of elements Brick blocks falling down			Component deformation Excessive deflection or deformations Walls or elements leaning out of vertical			Decay phenomena (wet area, exfoliation) Cracking of plaster or veneer Detachment of plaster or veneer			
			Nº of Floors: 6																				
			Area of single floor: 3860 m²																				
			Construction typology: R.C.																				
Nº of buildings blocks: 8																							
Building Condition Rating:																							
0.74																							
Tech. Unit		Element		Sub-element																			
Code	Type	Code	Typology	CCr	Code	Component																	
S	Str.	S2	Structural element	0.03	S2.2	Column																	
				0.09	S2.3	Beam																	
L	Load b.	L1	Slab	0.08	L1.4	Balcony or projection																	
		L2	Connection	0.00	L2.1	Staircase																	
N	Non load bearing	N1	Facade envelope	0.30	N1.1	Curtain wall																	
				0.00	N1.2	Windows fixture																	
		N2	External wall	0.00	N2.1	External R.C. wall																	
				0.00	N2.2	External brick wall																	
		N4	Other	0.00	N4.1	Joint between elements																	

P34	CITY		El Perellonet		MATRIX OF DAMAGE		Cod	Ox			Cr			Gi			Df			De			
	ADDRESS		Av de las Gaviotas		Registry data			R.C. Corrosion			Cracking pattern			Defect in giuntion and detachment			Component deformation			Plaster or finiscing decay			
					Total area: 3672 m ²			Ox1			Cr1			Gi1			Df1			De1			
					Nº of Floors: 8			Ox2			Cr2			Gi2			Df2			De2			
Decision Support System	Survey output				Area of single floor: 459 m ²		Building Damage	Cracks caused by rebar corrosion			Cracking pattern			Defects at junction			Detachment of elements			Brick blocks falling down			
					Construction typology: R.C.			Spalling			Medium cracks			Wide or active cracks			Component deformation			Excessive deflection or deformations			
					Nº of buildings blocks: 3			Heavy concrete spalling			Thin cracks			Detachment of elements			Component deformation			Walls or elements leaning out of vertical			
					Building Condition Rating:															Decay phenomena (wet area, exfoliation)			
Tech. Unit		Element		Sub-element																			
Code	Type	Code	Typology	CCr	Code	Component																	
S	Str.	S2	Structural element	0.03	S2.2	Column																	
				0.12	S2.3	Beam	9																
L	Load b.	L1	Slab	0.54	L1.4	Balcony or projection															18		
		L2	Connection	0.00	L2.1	Staircase																	
N	Non load bearing	N1	Facade envelope	0.08	N1.1	Curtain wall															8		
				0.00	N1.2	Windows fixture																	
		N2	External wall	0.00	N2.1	External R.C. wall																	
				0.00	N2.2	External brick wall																	
		N4	Other	0.00	N4.2	Joint between elements																	

P35	CITY		El Perellonet		MATRIX OF DAMAGE		Cod	Ox			Cr			Gi			Df			De		
	ADDRESS		Av de las Gaviotas		Registry data			R.C. Corrosion			Cracking pattern			Defect in giuntion and detachment			Component deformation			Plaster or finiscing decay		
					Total area: 5124 m ²			Ox1			Cr1			Gi1			Df1			De1		
					Nº of Floors: 6			Ox2			Cr2			Gi2			Df2			De2		
Decision Support System					Area of single floor: 845 m ²		Building Damage	Cracks caused by rebar corrosion			Cracking pattern			Defects at junction			Detachment of elements			Brick blocks falling down		
					Construction typology: R.C.			Spalling			Medium cracks			Wide or active cracks			Component deformation			Excessive deflection or deformations		
					Nº of buildings blocks: 2			Heavy concrete spalling			Thin cracks			Detachment of elements			Walls or elements leaning out of vertical					
					Building Condition Rating:												Decay phenomena (wet area, exfoliation)					
Tech. Unit		Element		Sub-element																		
Code	Type	Code	Typology	CCr	Code	Component																
S	Str.	S2	Structural element	0.00	S2.2	Column																
				0.00	S2.3	Beam			6									5				
L	Load b.	L1	Slab	0.00	L1.4	Balcony or projection												4				
		L2	Connection	0.00	L2.1	Staircase																
N	Non load bearing	N1	Facade envelope	0.00	N1.1	Curtain wall												21				
				0.00	N1.2	Windows fixture																
		N2	External wall	0.00	N2.1	External R.C. wall																
				0.00	N2.2	External brick wall																
		N4	Other	0.00	N4.1	Joint between elements																

P36	CITY		El Perellonet		MATRIX OF DAMAGE		Cod	Ox			Cr			Gi			Df			De		
	ADDRESS		Paseo de las Golas		Registry data			R.C. Corrosion			Cracking pattern			Defect in giuntion and detachment			Component deformation			Plaster or finiscing decay		
					Total area: 11200 m ²			Ox1			Cr1			Gi1			Df1			De1		
					Nº of Floors: 7			Ox2			Cr2			Gi2			Df2			De2		
Decision Support System	Survey output				Area of single floor: 1600 m ²		Building Damage	Cracks caused by rebar corrosion			Cracking pattern			Defects at junction			Detachment of elements			Brick blocks falling down		
					Construction typology: R.C.			Spalling			Medium cracks			Wide or active cracks			Component deformation			Excessive deflection or deformations		
					Nº of buildings blocks: 2			Heavy concrete spalling			Thin cracks			Detachment of elements			Component deformation			Walls or elements leaning out of vertical		
					Building Condition Rating:															Decay phenomena (wet area, exfoliation)		
Tech. Unit		Element		Sub-element																		
Code	Type	Code	Typology	CCr	Code	Component																
S	Str.	S2	Structural element	0.05	S2.2	Column																
				0.29	S2.3	Beam																
L	Load b.	L1	Slab	0.29	L1.1	Slab																
				1.14	L1.4	Balcony or projection																
N	Non load bearing	N1	Facade envelope	0.13	N1.1	Curtain wall																
				0.00	N1.2	Windows fixture																
		N2	External wall	0.00	N2.1	External R.C. wall																
				0.00	N2.2	External brick wall																
		N4	Other	0.00	N4.1	Joint between elements																

P37	CITY		El Perellonet		MATRIX OF DAMAGE		Cod. Macro Type	Ox			Cr			Gi			Df			De																	
	ADDRESS		Av de las Gaviotas		Registry data			R.C. Corrosion			Cracking pattern			Defect in giuntion and detachment			Component deformation			Plaster or finishing decay																	
			Total area: 4205 m²		Nº of Floors: 5			Area of single floor: 841 m²		Construction typology: R.C.		Nº of buildings blocks: 2		Building Condition Rating:																							
											1.52																										
Decision Support System Survey output								Cracks caused by rebar corrosion		Spalling		Heavy concrete spalling		Thin cracks		Medium cracks		Wide or active cracks		Defects at junction		Detachment of elements		Brick blocks falling down		Component deformation		Excessive deflection or deformations		Walls or elements tanning out of vertical		Decay phenomena (wet area, exfoliation)		Cracking of plaster or veneer		Detachment of plaster or veneer	
Tech. Unit		Element		Sub-element																																	
Code	Type	Code	Typology	CCr	Code	Component																															
S	Str.	S2	Structural element	0.22 0.23	S2.2 S2.3	Column Beam	1																											6			
L	Load b.	L1	Slab	0.00	L1.1	Slab																															
		L2	Connection	0.79	L1.4	Balcony or projection																															
				0.08 0.29	N1.1 N1.2	Curtain wall Windows fixture																															
N	Non load bearing	N2	External wall	0.00	N2.1	External R.C. wall									5																						
		N2	External wall	0.00	N2.2	External brick wall																															
		N4	Other	0.00	N4.1	Joint between elements																															

P38	CITY		El Perellonet		MATRIX OF DAMAGE		Macro Type	Ox			Cr			Gi			Df			De		
	ADDRESS		Paseo de las Golas		Registry data			R.C. Corrosion			Cracking pattern			Defect in giuntion and detachment			Component deformation			Plaster or finishing decay		
	Decision Support System Survey output				Total area: 3738 m² Nº of Floors: 7 Area of single floor: 53 m² Construction typology: R.C. Nº of buildings blocks: 3 Building Condition Rating: 0.08			Cracks caused by rebar corrosion			Spalling			Thin cracks			Medium cracks			Wide or active cracks		
Tech. Unit		Element			Sub-element		Cod. Type	Cracks caused by rebar corrosion			Spalling			Thin cracks			Medium cracks			Wide or active cracks		
Code	Type	Code	Typology	CCr	Code	Component		Ox1	Ox2	Ox3	Cr1	Cr2	Cr3	Gi1	Gi2	Gi3	Df1	Df2	Df3	De1	De2	De3
S	Str.	S2	Structural element	0.00 0.00	S2.2	Column																
					S2.3	Beam																
L	Load b.	L1	Slab	0.21	L1.4	Balcony or projection														6		
		L2	Connection	0.00	L2.1	Staircase																
N	Non load bearing	N1	Facade envelope	0.00 0.00	N1.1	Curtain wall																
					N1.2	Windows fixture																
		N2	External wall	0.00	N2.1	External R.C. wall																
					N2.2	External brick wall																
		N4	Other	0.00	N4.1	Joint between elements																

P39	CITY		El Perellonet		MATRIX OF DAMAGE		Cod. Macro Type	Ox			Cr			Gi			Df			De																	
	ADDRESS		Av de las Gaviotas		Registry data			R.C. Corrosion			Cracking pattern			Defect in giuntion and detachment			Component deformation			Plaster or finishing decay																	
			Total area: 4200 m ²		Nº of Floors: 7			Area of single floor: 600 m ²			Construction typology: R.C.			Nº of buildings blocks: 6			Building Condition Rating:																				
0.06																																					
Decision Support System Survey output						Building Damage		Cracks caused by rebar corrosion		Spalling		Heavy concrete spalling		Thin cracks		Medium cracks		Wide or active cracks		Defects at junction		Detachment of elements		Brick blocks falling down		Component deformation		Excessive deflection or deformations		Walls or elements leaning out of vertical		Decay phenomena (wet area, exfoliation)		Cracking of plaster or veneer		Detachment of plaster or veneer	
Tech. Unit		Element		Sub-element																																	
Code	Type	Code	Typology	CCr	Code	Component																															
S	Str.	S2	Structural element	0.00	S2.2	Column																															
				0.00	S2.3	Beam																															
L	Load b.	L1	Slab	0.00	L1.4	Balcony or projection																															
		L2	Connection	0.00	L2.1	Staircase																															
N	Non load bearing	N1	Facade envelope	0.01	N1.1	Curtain wall																															
				0.00	N1.2	Windows fixture																															
		N2	External wall	0.00	N2.1	External R.C. wall																															
				0.00	N2.2	External brick wall																															
		N4	Other	0.00	N4.1	Joint between elements																															

P40	CITY		El Perellonet		MATRIX OF DAMAGE		Cod Macro Type	Ox			Cr			Gi			Df			De		
	ADDRESS		Paseo de las Golas		Registry data			R.C. Corrosion			Cracking pattern			Defect in giuntion and detachment			Component deformation			Plaster or finiscing decay		
					Total area: 3900 m²			Ox1	Ox2	Ox3	Cr1	Cr2	Cr3	Gi1	Gi2	Gi3	Df1	Df2	Df3	De1	De2	De3
					Nº of Floors: 13			Building Damage Criticality	Cracks caused by rebar corrosion			Spalling			Heavy concrete spalling			Thin cracks			Medium cracks	
Decision Support System		Survey output		Area of single floor: 300 m²		Building Damage Criticality	Wide or active cracks			Defects at junction			Detachment of elements			Brick blocks falling down			Component deformation			
				Construction typology: R.C.			Excessive deflection or deformations			Walls or elements leaning out of vertical			Decay phenomena (wet area, exfoliation)			Cracking of plaster or veneer			Detachment of plaster or veneer			
				Nº of buildings blocks: 1																		
				Building Condition Rating:																		
				1.72																		
Tech. Unit		Element			Sub-element																	
Code	Type	Code	Typology	CCr	Code	Component																
S	Str.	S2	Structural element	0.00	S2.2	Column																
				0.00	S2.3	Beam																
L	Load b.	L1	Slab	3.30	L1.4	Balcony or projection	12												26			
		L2	Connection	0.00	L2.1	Staircase																
N	Non load bearing	N1	Facade envelope	0.04	N1.1	Curtain wall																
				0.00	N1.2	Windows fixture													4			
		N2	External wall	0.00	N2.1	External R.C. wall																
				0.00	N2.2	External brick wall																
		N4	Other	0.00	N4.1	Joint between elements																

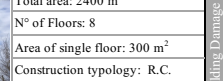
P41	CITY		El Perellonet		MATRIX OF DAMAGE		Cod Macro Type	Ox			Cr			Gi			Df			De																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																							
	ADDRESS		Av de las Gaviotas		Registry data			R.C. Corrosion			Cracking pattern			Defect in giuntion and detachment			Component deformation			Plaster or finiscing decay																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																							
					Total area: 4000 m²			Ox1	Ox2	Ox3	Cr1	Cr2	Cr3	Gi1	Gi2	Gi3	Df1	Df2	Df3	De1	De2	De3																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																					
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Decision Support System					Area of single floor: 800 m²		Cracks caused by rebar corrosion			Spalling			Heavy concrete spalling			Thin cracks			Medium cracks			Wide or active cracks			Defects at junction			Detachment of elements			Brick blocks falling down			Component deformation			Excessive deflection or deformations			Walls or elements leaning out of vertical			Decay phenomena (wet area, exfoliation)			Cracking of plaster or veneer			Detachment of plaster or veneer																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																										
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P42	CITY		El Perellonet		MATRIX OF DAMAGE		Cod Macro Type	Ox			Cr			Gi			Df			De		
	ADDRESS		Paseo de las Golas		Registry data			R.C. Corrosion			Cracking pattern			Defect in giuntion and detachment			Component deformation			Plaster or finiscing decay		
					Total area: 8522 m²			Ox1	Ox2	Ox3	Cr1	Cr2	Cr3	Gi1	Gi2	Gi3	Df1	Df2	Df3	De1	De2	De3
					Nº of Floors: 22			Building Damage Criticality	Cracks caused by rebar corrosion			Spalling			Heavy concrete spalling			Thin cracks			Medium cracks	
Tech. Unit		Element		Sub-element		Wide or active cracks			Defects at junction			Detachment of elements			Brick blocks falling down			Component deformation				
Code	Type	Code	Typology	CCr	Code	Component	Excessive deflection or deformations			Walls or elements leaning out of vertical			Decay phenomena (wet area, exfoliation)			Cracking of plaster or veneer			Detachment of plaster or veneer			
S	Str.	S2	Structural element	0.54 0.00	S2.2 S2.3	Column Beam														52		
L	Load b.	L1	Slab	1.19 0.00	L1.4 L2.1	Balcony or projection Staircase														36		
N	Non load bearing	N1	Facade envelope	1.07 0.00	N1.1 N1.2	Curtain wall Windows fixture														24		
				0.00 0.00	N2.1 N2.2	External R.C. wall External brick wall																
		N4	Other	0.00	N4.1	Joint between elements																

Decision Support System	Survey output		CITY		El Perellonet		MATRIX OF DAMAGE		Cod	Ox			Cr			Gi			Df			De																	
			ADDRESS		Paseo de las Golas		Registry data			R.C. Corrosion			Cracking pattern			Defect in giuntion and detachment			Component deformation			Plaster or finising decay																	
							Total area: 7200 m ²			Macro Damage	Criticality	Ox1	Ox2	Ox3	Cr1	Cr2	Cr3	Gi1	Gi2	Gi3	Df1	Df2	Df3	De1	De2	De3													
							Nº of Floors: 6																																
							Area of single floor: 1200 m ²																																
							Construction typology: R.C.																																
							Nº of buildings blocks: 5																																
			Building Condition Rating:																																				
			1.39																																				
			Tech. Unit		Element		Sub-element			Cracks caused by rebar corrosion		Spalling		Heavy concrete spalling		Thin cracks		Medium cracks		Wide or active cracks		Defects at junction		Detachment of elements		Brick blocks falling down		Component deformation		Excessive deflection or deformations		Walls or elements leaning out of vertical		Decay phenomena (wet area, exfoliation)		Cracking of plaster or veneer		Detachment of plaster or veneer	
			Code	Type	Code	Typology	CCr	Code		Component																													
S	Str.	S2	Structural element	0.29	S2.2	Column																																	
				0.27	S2.3	Beam																																	
L	Load b.	L1	Slab	-1.07	L1.4	Balcony or projection																																	
				0.00	L2.1	Staircase																																	
N	Non load bearing	N1	Facade envelope	0.00	N1.1	Curtain wall																																	
				0.00	N1.2	Windows fixture																																	
		N2	External wall	0.00	N2.1	External R.C. wall																																	
				0.00	N2.2	External brick wall																																	
		N4	Other	0.00	N4.1	Joint between elements																																	

P44		CITY		El Perellonet		MATRIX OF DAMAGE		Cod	Ox			Cr			Gi			Df			De																																
		ADDRESS		Calle de Mesana		Registry data			R.C. Corrosion			Cracking pattern			Defect in giuntion and detachment			Component deformation			Plaster or finising decay																																
Decision Support System	Survey output			Total area: 7800 m² Nº of Floors: 5 Area of single floor: 1560 m² Construction typology: R.C. Nº of buildings blocks: 4 Building Condition Rating: 0.09		Building Damage			Cracks caused by rebar corrosion			Spalling			Heavy concrete spalling			Thin cracks			Medium cracks																																
									Ox1			Ox2			Ox3			Cr1			Cr2			Cr3			Gi1			Gi2			Gi3			Df1			Df2			Df3			De1			De2			De3		
									Criticality																																												
									Cracks caused by rebar corrosion			Spalling			Heavy concrete spalling			Thin cracks			Medium cracks			Wide or active cracks			Defects at junction			Detachment of elements			Brick blocks falling down			Component deformation			Excessive deflection or deformations			Walls or elements leaning out of vertical			Decay phenomena (wet area, exfoliation)			Cracking of plaster or veneer			Detachment of plaster or veneer		
Tech. Unit		Element		Sub-element																																																	
Code	Type	Code	Typology	CCr	Code	Component																																															
S	Str.	S2	Structural element	0.06	S2.2	Column																																															
				0.01	S2.3	Beam																																															
L	Load b.	L1	Slab	0.04	L1.4	Balcony or projection																																															
				0.00	L2.1	Staircase																																															
N	Non load bearing	N1	Facade envelope	0.03	N1.1	Curtain wall																																															
				0.00	N1.2	Windows fixture																																															
		N2	External wall	0.00	N2.1	External R.C. wall																																															
				0.00	N2.2	External brick wall																																															
		N4	Other	0.00	N4.1	Joint between elements																																															

P45	CITY:		El Perellonet		MATRIX OF DAMAGE		Cod	Ox			Cr			Gi			Df			De																	
	ADDRESS		Calle de Mesana		Registry data			R.C. Corrosion			Cracking pattern			Defect in giuntion and detachment			Component deformation			Plaster or finising decay																	
					Total area: m²			Macro Age	Criticality	Ox1	Ox2	Ox3	Cr1	Cr2	Cr3	Gi1	Gi2	Gi3	Df1	Df2	Df3	De1	De2	De3													
					Nº of Floors:																																
					Area of single floor: m²																																
					Construction typology: R.C.																																
					Nº of buildings blocks:																																
	Building Condition Rating:		0.05																																		
	Decision Support System		Survey output		Building Damage			Cracks caused by rebar corrosion		Spalling		Heavy concrete spalling		Thin cracks		Medium cracks		Wide or active cracks		Defects at junction		Detachment of elements		Brick blocks falling down		Component deformation		Excessive deflection or deformations		Walls or elements leaning out of vertical		Decay phenomena (wet area, exfoliation)		Cracking of plaster or veneer		Detachment of plaster or veneer	
	Tech. Unit		Element		Sub-element																																
Code	Type	Code	Typology	CCr	Code	Component																															
S	Str.	S2	Structural element	0.06	S2.2	Column																															
				0.01	S2.3	Beam																															
L	Load b.	L1	Slab	0.02	L1.4	Balcony or projection																															
		L2	Connection	0.00	L2.1	Staircase																															
N	Non load bearing	N1	Facade envelope	0.03	N1.1	Curtain wall																															
				0.00	N1.2	Windows fixture																															
		N2	External wall	0.00	N2.1	External R.C. wall																															
				0.00	N2.2	External brick wall																															
		N4	Other	0.00	N4.1	Joint between elements																															

PAB	CITY		El Perellonet		MATRIX OF DAMAGE		Macro Type	Ox			Cr			Gi			Df			De			
	ADDRESS		Calle de la Botavara		Registry data			Cracks caused by rebar corrosion	R.C. Corrosion			Cracking pattern			Defect in giuntion and detachment			Component deformation			Plaster or finishing decay		
									Ox1	Ox2	Ox3	Cr1	Cr2	Cr3	Gi1	Gi2	Gi3	Df1	Df2	Df3	De1	De2	De3
Decision Support System Survey output					Total area: 2400 m ²		Building Damage	R.C. Corrosion			Cracking pattern			Defect in giuntion and detachment			Component deformation			Plaster or finishing decay			
					Nº of Floors: 8			Ox1			Cr1			Gi1			Df1			De1			
					Area of single floor: 300 m ²			Ox2			Cr2			Gi2			Df2			De2			
					Construction typology: R.C.			Ox3			Cr3			Gi3			Df3			De3			
					Nº of buildings blocks:																		
					Building Condition Rating:																		
					2.6																		
Tech. Unit		Element				Sub-element																	
Code	Type	Code	Typology	CCr	Code	Component																	
S	Str.	S2	Structural element	0.57	S2.2	Column	2	Spalling			Heavy concrete spalling												
				0.27	S2.3	Beam																	
L	Load b.	L1	Slab	1.16	L1.4	Balcony or projection																	
		L2	Connection	0.00	L2.1	Staircase																	
N	Non load bearing	N1	Facade envelope	0.49	N1.1	Curtain wall																	
				0.00	N1.2	Windows fixture																	
		N2	External wall	0.00	N2.1	External R.C. wall																	
		N2		0.00	N2.2	External brick wall																	
		N4	Other	0.00	N4.1	Joint between elements											16						

P49	CITY		El Perellonet		MATRIX OF DAMAGE		Cod	Ox			Cr			Gi			Df			De										
	ADDRESS		Traversia Cala Moreno		Registry data			R.C. Corrosion			Cracking pattern			Defect in giuntion and detachment			Component deformation			Plaster or finising decay										
					Total area: 1800 m ²			Ox1	Ox2	Ox3	Cr1	Cr2	Cr3	Gi1	Gi2	Gi3	Df1	Df2	Df3	De1	De2	De3								
					N° of Floors: 6																									
Decision Support System		Survey output		Area of single floor: 300 m ²		Construction typology: R.C.		N° of buildings blocks: 1		Building Condition Rating:																				
				0.09																										

P50	CITY		El Perellonet		MATRIX OF DAMAGE		Cod	Ox			Cr			Gi			Df			De										
	ADDRESS		Calle cabrestante		Registry data			R.C. Corrosion			Cracking pattern			Defect in giuntion and detachment			Component deformation			Plaster or finising decay										
					Total area: 5000 m²			Ox1	Ox2	Ox3	Cr1	Cr2	Cr3	Gi1	Gi2	Gi3	Df1	Df2	Df3	De1	De2	De3								
					Nº of Floors: 5																									
Decision Support System					Area of single floor: 1000 m²		Cracks caused by rebar corrosion	Spalling		Heavy concrete spalling		Thin cracks				Medium cracks		Wide or active cracks			Defects at junction		Detachment of elements	Brick blocks falling down	Component deformation	Excessive deflection or deformations	Walls or elements leaning out of vertical	Decay phenomena (wet area, exfoliation)	Cracking of plaster or veneer	Detachment of plaster or veneer
					Construction typology: R.C.																									
					Nº of buildings blocks: 6																									
Survey output				Building Condition Rating:																										
				7.5																										

Tech. Unit		Element		Sub-element		Cracks caused by rebar corrosion	Spalling	Heavy concrete spalling	Thin cracks	Medium cracks	Wide or active cracks	Defects at junction	Detachment of elements	Brick blocks falling down	Component deformation	Excessive deflection or deformations	Walls or elements leaning out of vertical	Decay phenomena (wet area, exfoliation)	Cracking of plaster or veneer	Detachment of plaster or veneer
Code	Type	Code	Typology	CCr	Code															
S	Str.	S2	Structural element	1.24	S2.2	Column	10		10					5						5
					1.50	S2.3	Beam					12					1	1		57
L	Load b.	L1	Slab	6.34	L1.4	Balcony or projection				14				1					75	
		L2	Connection	0.00	L2.1	Staircase														
N	Non load bearing	N1	Facade envelope	0.14	N1.1	Curtain wall													16	
				0.00	N1.2	Windows fixture														
		N2	External wall	0.00	N2.1	External R.C. wall														
				0.00	N2.2	External brick wall														
		N4	Other	0.00	N4.1	Joint between elements														

P51		CITY		El Perellonet		MATRIX OF DAMAGE		Cod	Ox			Cr			Gi			Df			De																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																														
		ADDRESS		Calle Cabrestante		Registry data			R.C. Corrosion			Cracking pattern			Defect in giuntion and detachment			Component deformation			Plaster or finising decay																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																														
Decision Support System	Survey output					Total area: 5000 m²		Building Damage	Criticality	Micro Age	Ox1	Ox2	Ox3	Cr1	Cr2	Cr3	Gi1	Gi2	Gi3	Df1	Df2	Df3	De1	De2	De3																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																										
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						Area of single floor: 1000 m²																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																													
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Building Condition Rating:																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																			
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Tech. Unit		Element		Sub-element						Cracks caused by rebar corrosion		Spalling		Heavy concrete spalling		Thin cracks		Medium cracks		Wide or active cracks		Defects at junction		Detachment of elements		Brick blocks falling down		Component deformation		Excessive deflection or deformations		Walls or elements leaning out of vertical		Decay phenomena (wet area, exfoliation)		Cracking of plaster or veneer		Detachment of plaster or veneer																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																													
Code	Type	Code	Typology	CCr	Code	Component																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																													
S	Str.	S2	Structural element	0.70	S2.2	Column	10																													20																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																															
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P52	CITY		El Porellonet		MATRIX OF DAMAGE		Cod	Ox			Cr			Gi			Df			De		
	ADDRESS		Calle Cabrestante		Registry data			R.C. Corrosion			Cracking pattern			Defect in giuntion and detachment			Component deformation			Plaster or finishing decay		
					Total area: 7800 m²			Ox1			Cr1			Gi1			Df1			De1		
					Nº of Floors: 6			Ox2		Cr2		Gi2		Df2		De2						
Area of single floor: 1300 m²					Ox3		Cr3		Gi3		Df3		De3									
Decision Support System Survey output					Construction typology: R.C.		Building Damage Criticality	Cracks caused by rebar corrosion			Cracking pattern			Defects at junction			Component deformation			Decay phenomena (wet area, exfoliation)		
					Nº of buildings blocks: 7			Spalling			Medium cracks			Detachment of elements			Excessive deflection or deformations			Cracking of plaster or veneer		
					Building Condition Rating:			Heavy concrete spalling			Wide or active cracks			Brick blocks falling down			Walls or elements leaning out of vertical			Detachment of plaster or veneer		
					9.7																	
Tech. Unit		Element		Sub-element																		
Code	Type	Code	Typology	CCr	Code	Component																
S	Str.	S2	Structural element	0.02	S2.2	Column	12															
				1.16	S2.3	Beam																
L	Load b.	L1	Slab	8.29	L1.4	Balcony or projection	72	28	14											40	40	
		L2	Connection	0.00	L2.1	Staircase																
N	Non load bearing	N1	Facade envelope	2.40	N1.1	Curtain wall														135	45	
				0.00	N1.2	Windows fixture																
		N2	External wall	0.00	N2.1	External R.C. wall																
				0.00	N2.2	External brick wall																
		N4	Other	0.00	N4.1	Joint between elements																

P53	CITY		El Perellonet		MATRIX OF DAMAGE		Cod	Ox			Cr			Gi			Df			De		
	ADDRESS		Calle de sotavento		Registry data			R.C. Corrosion			Cracking pattern			Defect in giuntion and detachment			Component deformation			Plaster or finishing decay		
					Total area: 6500 m ²			Ox1			Cr1			Gi1			Df1			De1		
					Nº of Floors: 5			Ox2		Cr2		Gi2		Df2		De2						
Decision Support System Survey output					Area of single floor: 1300 m ²		Building Damage Criticality	Ox3			Cr3			Gi3			Df3			De3		
					Construction typology: R.C.			Cracks caused by rebar corrosion			Medium cracks			Defects at junction			Component deformation			Decay phenomena (wet area, exfoliation)		
					Nº of buildings blocks: 2			Spalling			Wide or active cracks			Detachment of elements			Excessive deflection or deformations			Cracking of plaster or veneer		
					Building Condition Rating:			Heavy concrete spalling			Brick blocks falling down			Walls or elements leaning out of vertical			Detachment of plaster or veneer					
Tech. Unit		Element		Sub-element																		
Code	Type	Code	Typology	CCr	Code	Component																
S	Str.	S2	Structural element	0.00	S2.2	Column																
				0.23	S2.3	Beam	16															
L	Load b.	L1	Slab	0.89	L1.4	Balcony or projection																
		L2	Connection	0.00	L2.1	Staircase																
N	Non load bearing	N1	Facade envelope	0.22	N1.1	Curtain wall																
				0.00	N1.2	Windows fixture																
		N2	External wall	0.00	N2.1	External R.C. wall																
				0.00	N2.2	External brick wall																
		N4	Other	0.00	N4.1	Joint between elements																

Playa Puebla de Farnals

F1		CITY		Puebla de Farnals		MATRIX OF DAMAGE		Macro type	Ox			Cr			Gi			Df			De																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																					
ADDRESS		Calle de los Serrans		Registry data		R.C. Corrosion			Cracking pattern			Defect in giuntion and detachment			Component deformation			Plaster or finishing decay																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																								
				Total area: 6454 m² Nº of Floors: 14 Area of single floor: 461 m² Construction typology: R.C. Nº of buildings blocks: 1 Building Condition Rating: 0.75		Cracks caused by rebar corrosion			Spalling			Heavy concrete spalling			Thin cracks			Medium cracks			Wide or active cracks			Defects at junction			Detachment of elements			Brick blocks falling down			Component deformation			Excessive deflection or deformations			Walls or elements leaning out of vertical			Decay phenomena (wet area, exfoliation)			Cracking of plaster or veneer			Detachment of plaster or veneer																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																										
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Decision Support System	Survey output	CITY		Puebla de Farnals		MATRIX OF DAMAGE		Macro type	Ox			Cr			Gi			Df			De		
		ADDRESS		Calle de los Serrans		Registry data			R.C. Corrosion			Cracking pattern			Defect in giuntion and detachment			Component deformation			Plaster or finishing decay		
									Ox1	Ox2	Ox3	Cr1	Cr2	Cr3	Gi1	Gi2	Gi3	Df1	Df2	Df3	De1	De2	De3
									Cracks caused by rebar corrosion	Spalling	Heavy concrete spalling	Thin cracks	Medium cracks	Wide or active cracks	Defects at junction	Detachment of elements	Brick blocks falling down	Component deformation	Excessive deflection or deformations	Walls or elements leaning out of vertical	Decay phenomena (wet area, exfoliation)	Cracking of plaster or veneer	Detachment of plaster or veneer
Tech. Unit		Element				Sub-element																	
Code	Type	Code	Typology		CCr	Code	Component																
S	Str.	S2	Structural element		0.00	S2.2	Column																
					0.00	S2.3			Beam														
L	Load b.	L1	Slab		0.37	L1.4	Balcony or projection																
					0.00	L2.1			Staircase														
N	Non load bearing	N1	Facade envelope		0.50	N1.1	Curtain wall																
					0.00	N1.2			Windows fixture														
		N2	External wall		0.00	N2.1	External R.C. wall																
					0.00	N2.2			External brick wall														
		Other			0.00	N4.1	Joint between elements																

F4	CITY		Puebla de Farnals		MATRIX OF DAMAGE		Cod	Ox			Cr			Gi			Df			De		
	ADDRESS		Av. de Massamagrell		Registry data			R.C. Corrosion			Cracking pattern			Defect in giuntion and detachment			Component deformation			Plaster or finishing decay		
			Total area: 6454 m² Nº of Floors: 14 Area of single floor: 461 m² Construction typology: R.C. Nº of buildings blocks: 1 Building Condition Rating: 0.75		Building Damage	Cracks caused by rebar corrosion			Thin cracks			Defects at junction			Component deformation			Decay phenomena (wet area, exfoliation)				
Spalling						Medium cracks			Detachment of elements			Excessive deflection or deformations			Cracking of plaster or veneer							
Heavy concrete spalling						Wide or active cracks			Brick blocks falling down			Walls or elements leaning out of vertical			Detachment of plaster or veneer							
Tech. Unit		Element		Sub-element																		
Code	Type	Code	Typology	CCr	Code	Component																
S	Str.	S2	Structural element	0.80	S2.2	Column																
				0.00	S2.3	Beam																
L	Load b.	L1	Slab	0.00	L1.4	Balcony or projection																
		L2	Connection	0.00	L2.1	Staircase																
N	Non load bearing	N1	Facade envelope	0.50	N1.1	Curtain wall														15		
				0.00	N1.2	Windows fixture																
		N2	External wall	0.00	N2.1	External R.C. wall																
				0.00	N2.2	External brick wall																
		N4	Other	0.00	N4.1	Joint between elements																

F5	CITY		Puebla de Farnals		MATRIX OF DAMAGE		Cod	Ox			Cr			Gi			Df			De		
	ADDRESS		Av. de Massamagrell		Registry data			R.C. Corrosion			Cracking pattern			Defect in giuntion and detachment			Component deformation			Plaster or finiscing decay		
								Ox1	Ox2	Ox3	Cr1	Cr2	Cr3	Gi1	Gi2	Gi3	Df1	Df2	Df3	De1	De2	De3
Decision Support System	Survey output				Total area: 8576 m²		Building Damage	Cracks caused by rebar corrosion	Spalling	Heavy concrete spalling	Thin cracks	Medium cracks	Wide or active cracks	Defects at junction	Detachment of elements	Brick blocks falling down	Component deformation	Excessive deflection or deformations	Walls or elements leaning out of vertical	Decay phenomena (wet area, exfoliation)	Cracking of plaster or veneer	Detachment of plaster or veneer
					Nº of Floors: 16																	
					Area of single floor: 536 m²																	
					Construction typology: R.C.																	
					Nº of buildings blocks: 2																	
					Building Condition Rating:																	
					0.02																	
Tech. Unit		Element		Sub-element																		
Code	Type	Code	Typology	CCr	Code	Component																
S	Str.	S2	Structural element	0.00	S2.2	Column																
				0.00	S2.3	Beam																
L	Load b.	L1	Slab	0.00	L1.4	Balcony or projection																
		L2	Connection	0.00	L2.1	Staircase																
N	Non load bearing	N1	Facade envelope	0.01	N1.1	Curtain wall													2			
				0.00	N1.2	Windows fixture																
		N2	External wall	0.00	N2.1	External R.C. wall																
				0.00	N2.2	External brick wall																
		N4	Other	0.00	N4.1	Joint between elements																

F6	CITY		Puebla de Farnals		MATRIX OF DAMAGE		Cod	Ox			Cr			Gi			Df			De		
	ADDRESS		Av. de Massamagrell		Registry data			R.C. Corrosion			Cracking pattern			Defect in giuntion and detachment			Component deformation			Plaster or finishing decay		
								Ox1	Ox2	Ox3	Cr1	Cr2	Cr3	Gi1	Gi2	Gi3	Df1	Df2	Df3	De1	De2	De3
Decision Support System	Survey output			Total area: 8576 m² Nº of Floors: 16 Area of single floor: 536 m² Construction typology: R.C. Nº of buildings blocks: 2 Building Condition Rating: 1.65		Building Damage	Macro Type	Cracks caused by rebar corrosion			Thin cracks			Defects at junction			Component deformation			Decay phenomena (wet area, exfoliation)		
								Spalling	Heavy concrete spalling		Medium cracks	Wide or active cracks		Detachment of elements	Brick blocks falling down		Excessive deflection or deformations	Walls or elements leaning out of vertical		Cracking of plaster or veneer	Detachment of plaster or veneer	
Tech. Unit		Element		Sub-element																		
Code	Type	Code	Typology	CCr	Code	Component																
S	Str.	S2	Structural element	1.14	S2.2	Column	12															
				1.18	S2.3	Beam	16															
L	Load b.	L1	Slab	1.87	L1.4	Balcony or projection	12													46		
		L2	Connection	0.00	L2.1	Staircase																
N	Non load bearing	N1	Facade envelope	0.15	N1.1	Curtain wall														30		
				0.00	N1.2	Windows fixture																
		N2	External wall	0.00	N2.1	External R.C. wall																
				0.00	N2.2	External brick wall																
		N4	Other	0.00	N4.1	Joint between elements																

F7	CITY		Puebla de Famals		MATRIX OF DAMAGE		Cod. Type	Ox			Cr			Gi			Df			De																														
	ADDRESS		Avenida madrid		Registry data			R.C. Corrosion			Cracking pattern			Defect in giuntion and detachment			Component deformation			Plaster or finishing decay																														
	Survey output				Total area: 4500 m² Nº of Floors:1 Area of single floor: 300 m² Construction typology: R.C. Nº of buildings blocks: 1 Building Condition Rating: 0.05			Cracks caused by rebar corrosion			Cracking pattern			Defects at junction			Detachment of elements			Brick blocks falling down			Component deformation			Excessive deflection or deformations			Walls or elements leaning out of vertical			Decay phenomena (wet area, exfoliation)			Cracking of plaster or veneer			Detachment of plaster or veneer												
Tech. Unit		Element		Sub-element		Cracks caused by rebar corrosion			Spalling			Heavy concrete spalling			Thin cracks			Medium cracks			Wide or active cracks			Defects at junction			Detachment of elements			Brick blocks falling down			Component deformation			Excessive deflection or deformations			Walls or elements leaning out of vertical			Decay phenomena (wet area, exfoliation)			Cracking of plaster or veneer			Detachment of plaster or veneer		
Code	Type	Code	Typology	CCr	Code	Component																																												
S	Str.	S2	Structural element	0.00	S2.2	Column																																												
				0.00	S2.3	Beam																																												
L	Load b.	L1	Slab	0.00	L1.4	Balcony or projection																																												
				0.00	L2.1	Staircase																																												
N	Non load bearing	N1	Facade envelope	0.12	N1.1	Curtain wall																																												
				0.00	N1.2	Windows fixture																																												
				0.00	N2.1	External R.C. wall																																												
				0.00	N2.2	External brick wall																																												
				0.00	N4.1	Joint between elements																																												

F8	CITY		Puebla de Famals		MATRIX OF DAMAGE		Cod. Type	Ox			Cr			Gi			Df			De																			
	ADDRESS		Avenida madrid		Registry data			R.C. Corrosion			Cracking pattern			Defect in giuntion and detachment			Component deformation			Plaster or finiscing decay																			
			Total area: 6880 m ²		Nº of Floors: 16			Area of single floor: 430 m ²		Construction typology: R.C.		Nº of buildings blocks: 1		Building Condition Rating:																									
Decision Support System		Survey output		Building Damage		Macro Type		Criticality		Cracks caused by rebar corrosion		Spalling		Heavy concrete spalling		Thin cracks		Medium cracks		Wide or active cracks		Defects at junction		Detachment of elements		Brick blocks falling down		Component deformation		Excessive deflection or deformations		Walls or elements leaning out of vertical		Decay phenomena (wet area, exfoliation)		Cracking of plaster or veneer		Detachment of plaster or veneer	
Tech. Unit		Element		Sub-element																																			
Code	Type	Code	Typology	CCr	Code	Component																																	
S	Str.	S2	Structural element	0.00	S2.2	Column																																	
				0.00	S2.3	Beam																																	
L	Load b.	L1	Slab	0.00	L1.4	Balcony or projection																																	
		L2	Connection	0.00	L2.1	Staircase																																	
N	Non load bearing	N1	Facade envelope	0.08	N1.1	Curtain wall																																	
				0.00	N1.2	Windows fixture																																	
				0.00	N2.1	External R.C. wall																																	
		N2	External wall	0.00	N2.2	External brick wall																																	
				0.00	N4.1	Joint between elements																																	

F9	CITY		Puebla de Famals		MATRIX OF DAMAGE		Cod. Type	Ox			Cr			Gi			Df			De																			
	ADDRESS		Avenida madrid		Registry data			R.C. Corrosion			Cracking pattern			Defect in giuntion and detachment			Component deformation			Plaster or finishing decay																			
			Total area: 6880 m² Nº of Floors: 16 Area of single floor: 430 m² Construction typology: R.C. Nº of buildings blocks: 2 Building Condition Rating: 0.08		Cracks caused by rebar corrosion			Cracking pattern			Defects at junction			Detachment of elements			Brick blocks falling down			Component deformation			Excessive deflection or deformations			Walls or elements leaning out of vertical			Decay phenomena (wet area, exfoliation)			Cracking of plaster or veneer			Detachment of plaster or veneer				
					Ox1	Ox2		Ox3	Cr1	Cr2	Cr3	Gi1	Gi2	Gi3	Df1	Df2	Df3	De1	De2	De3																			
Decision Support System	Survey output						Building Damage	Cod	Criticality																														
Tech. Unit		Element				Sub-element																																	
Code	Type	Code	Typology		CCr	Code	Component																																
S	Str.	S2	Structural element		0.03	S2.2	Column																																
					0.00	S2.3	Beam																																
L	Load b.	L1	Slab		0.01	L1.4	Balcony or projection																																
		L2	Connection		0.00	L2.1	Staircase																																
					0.03	N1.1	Curtain wall																																
		N1	Facade envelope		0.00	N1.2	Windows fixture																																
					0.00	N2.1	External R.C. wall																																
		N2	External wall		0.00	N2.2	External brick wall																																
					0.00	N4.1	Joint between elements																																
		N4	Other		0.00																																		

F10	CITY		Puebla de Famals		MATRIX OF DAMAGE		Cod	Ox			Cr			Gi			Df			De																																
	ADDRESS		Av. de Massamagrell		Registry data			R.C. Corrosion			Cracking pattern			Defect in giuntion and detachment			Component deformation			Plaster or finiscing decay																																
Decision Support System Survey output					Total area: 21200 m ² N° of Floors: 16 Area of single floor: 1325 m ² Construction typology: R.C. N° of buildings blocks: 2 Building Condition Rating: 0.01		Building Damage Criticality	Cracks caused by rebar corrosion			Spalling			Heavy concrete spalling			Thin cracks			Medium cracks			Wide or active cracks			Defects at junction			Detachment of elements			Brick blocks falling down			Component deformation			Excessive deflection or deformations			Walls or elements leaning out of vertical			Decay phenomena (wet area, exfoliation)			Cracking of plaster or veneer			Detachment of plaster or veneer		
								Ox1	Ox2	Ox3	Cr1	Cr2	Cr3	Gi1	Gi2	Gi3	Df1	Df2	Df3	De1	De2	De3																														
Tech. Unit			Element			Sub-element																																														
Code	Type		Code	Typology	CCr	Code	Component																																													
S	Str.	S2	Structural element	0.00	S2.2		Column																																													
				0.00	S2.3		Beam																																													
L	Load b.	L1	Slab	0.00	L1.4		Balcony or projection																																													
		L2	Connection	0.00	L2.1		Staircase																																													
N	Non load bearing	N1	Facade envelope	0.01	N1.1		Curtain wall													5																																
				0.00	N1.2		Windows fixture																																													
		N2	External wall	0.00	N2.1		External R.C. wall																																													
				0.00	N2.2		External brick wall																																													
		N4	Other	0.00	N4.1		Joint between elements																																													

F11	CITY		Puebla de Famals		MATRIX OF DAMAGE		Cod	Ox			Cr			Gi			Df			De																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																														
	ADDRESS		Av. de Massamagrell		Registry data			R.C. Corrosion			Cracking pattern			Defect in giuntion and detachment			Component deformation			Plaster or finiscing decay																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																														
					Total area: 3704 m ² Nº of Floors: 8 Area of single floor: 463 m ² Construction typology: R.C. Nº of buildings blocks: 1 Building Condition Rating: 0.16			Cracks caused by rebar corrosion			Spalling			Heavy concrete spalling			Thin cracks			Medium cracks			Wide or active cracks			Defects at junction			Detachment of elements			Brick blocks falling down			Component deformation			Excessive deflection or deformations			Walls or elements leaning out of vertical			Decay phenomena (wet area, exfoliation)			Cracking of plaster or veneer			Detachment of plaster or veneer																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																
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F12	CITY		El Perellonet		MATRIX OF DAMAGE		Cod	Ox			Cr			Gi			Df			De																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																			
	ADDRESS		Avenida madrid		Registry data			R.C. Corrosion			Cracking pattern			Defect in giuntion and detachment			Component deformation			Plaster or finiscing decay																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																			
			Total area: 3704 m² Nº of Floors: 8 Area of single floor: 463 m² Construction typology: R.C. Nº of buildings blocks: 1 Building Condition Rating: 4.06		Cracks caused by rebar corrosion			Spalling			Heavy concrete spalling			Thin cracks			Medium cracks			Wide or active cracks			Defects at junction			Detachment of elements			Brick blocks falling down			Component deformation			Excessive deflection or deformations			Walls or elements leaning out of vertical			Decay phenomena (wet area, exfoliation)			Cracking of plaster or veneer			Detachment of plaster or veneer																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																								
					Ox1	Ox2		Ox3	Cr1	Cr2	Cr3	Gi1	Gi2	Gi3	Df1	Df2	Df3	De1	De2	De3																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																			
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S	Str.	S2	Structural element	0.00	S2.2	Column																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																	
				0.80	S2.3	Beam	9		5																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																														

F13	CITY		Puebla de Famals		MATRIX OF DAMAGE		Cod	Ox			Cr			Gi			Df			De		
	ADDRESS		Avenida madrid		Registry data			R.C. Corrosion			Cracking pattern			Defect in giuntion and detachment			Component deformation			Plaster or finishing decay		
					Total area: 3704 m² Nº of Floors: 8 Area of single floor: 463 m² Construction typology: R.C. Nº of buildings blocks: 1 Building Condition Rating: 3.84			Ox1			Cr1			Gi1			Df1			De1		
								Ox2			Cr2			Gi2			Df2			De2		
								Ox3			Cr3			Gi3			Df3			De3		
								Ox4			Cr4			Gi4			Df4			De4		
								Ox5			Cr5			Gi5			Df5			De5		
Tech. Unit		Element		Sub-element		Cracks caused by rebar corrosion			Spalling			Heavy concrete spalling			Thin cracks			Medium cracks				
Code	Type	Code	Typology	CCr	Code	Component																
S	Str.	S2	Structural element	0.33	S2.2	Column	12															
				0.42	S2.3	Beam	16															
L	Load b.	L1	Slab	4.33	L1.4	Balcony or projection	46													12		
		L2	Connection	0.00	L2.1	Staircase																
N	Non load bearing	N1	Facade envelope	0.36	N1.1	Curtain wall														30		
				0.00	N1.2	Windows fixture																
		N2	External wall	0.00	N2.1	External R.C. wall																
				0.00	N2.2	External brick wall																
		N4	Other	0.00	N4.1	Joint between elements																

F14	CITY		Puebla de Famals		MATRIX OF DAMAGE		Cod	Ox			Cr			Gi			Df			De				
	ADDRESS		Avenida madrid		Registry data			R.C. Corrosion			Cracking pattern			Defect in giuntion and detachment			Component deformation			Plaster or finishing decay				
					Total area: 2640 m²			Building Damage	Criticality	Ox1	Ox2	Ox3	Cr1	Cr2	Cr3	Gi1	Gi2	Gi3	Df1	Df2	Df3	De1	De2	De3
					Nº of Floors: 8																			
					Area of single floor: 330 m²																			
					Construction typology: R.C.																			
					Nº of buildings blocks: 1																			
Building Condition Rating:																								
1.9																								
Tech. Unit		Element		Sub-element																				
Code	Type	Code	Typology	CCr	Code	Component																		
S	Str.	S2	Structural element	0.00	S2.2	Column																		
				0.27	S2.3	Beam																		
L	Load b.	L1	Slab	2.20	L1.4	Balcony or projection																		29
		L2	Connection	0.00	L2.1	Staircase																		
N	Non load bearing	N1	Facade envelope	0.27	N1.1	Curtain wall																		16
				0.00	N1.2	Windows fixture																		
		N2	External wall	0.00	N2.1	External R.C. wall																		
				0.00	N2.2	External brick wall																		
		N4	Other	0.00	N4.1	Joint between elements																		

F15	CITY		Puebla de Famals		MATRIX OF DAMAGE		Cod	Ox			Cr			Gi			Df			De					
	ADDRESS		Calle de la Marina		Registry data			R.C. Corrosion			Cracking pattern			Defect in giuntion and detachment			Component deformation			Plaster or finishing decay					
					Total area: 3960 m² Nº of Floors: 12 Area of single floor: 330 m² Construction typology: R.C. Nº of buildings blocks: 1 Building Condition Rating: 1.6			Ox1			Cr1			Gi1			Df1			De1					
								Ox2			Cr2			Gi2			Df2			De2					
								Ox3			Cr3			Gi3			Df3			De3					
								Macro Type			Criticality			Cracks caused by rebar corrosion			Spalling			Heavy concrete spalling			Thin cracks		
								Medium cracks			Wide or active cracks			Defects at junction			Detachment of elements			Brick blocks falling down			Component deformation		
Excessive deflection or deformations			Walls or elements leaning out of vertical			Decay phenomena (wet area, exfoliation)			Cracking of plaster or veneer			Detachment of plaster or veneer													
Tech. Unit		Element		Sub-element																					
Code	Type	Code	Typology	CCr	Code	Component																			
S	Str.	S2	Structural element	0.00	S2.2	Column																			
				0.26	S2.3	Beam		3											10						
L	Load b.	L1	Slab	1.23	L1.4	Balcony or projection													16						
		L2	Connection	0.00	L2.1	Staircase																			
N	Non load bearing	N1	Facade envelope	0.39	N1.1	Curtain wall													24						
				0.00	N1.2	Windows fixture																			
		N2	External wall	0.00	N2.1	External R.C. wall																			
				0.00	N2.2	External brick wall																			
		N4	Other	0.00	N4.1	Joint between elements																			

F16	CITY		Puebla de Farnals		MATRIX OF DAMAGE		Cod Type	Ox			Cr			Gi			Df			De																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																	
	ADDRESS		Av. De Neptuno		Registry data			R.C. Corrosion			Cracking pattern			Defect in giuntion and detachment			Component deformation			Plaster or finiscing decay																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																	
					Total area: 6600 m²			Cod	Ox1	Ox2	Ox3	Cr1	Cr2	Cr3	Gi1	Gi2	Gi3	Df1	Df2	Df3	De1	De2	De3																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																														
					Nº of Floors: 6																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																
					Area of single floor: 1100 m²																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																
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Decision Support System		Survey output		Building Damage		Criticality		Cracks caused by rebar corrosion			Cracks caused by rebar corrosion			Cracks caused by rebar corrosion			Cracks caused by rebar corrosion																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																				
Tech. Unit		Element		Sub-element		Spalling			Heavy concrete spalling			Thin cracks			Medium cracks			Wide or active cracks			Defects at junction			Detachment of elements			Brick blocks falling down			Component deformation			Excessive deflection or deformations			Walls or elements leaning out of vertical			Decay phenomena (wet area, exfoliation)			Cracking of plaster or veneer			Detachment of plaster or veneer																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																								
Code	Type	Code	Typology	CCR	Code	Component																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																															</

F17	CITY		Puebla de Farnals		MATRIX OF DAMAGE		Cod Type	Ox			Cr			Gi			Df			De																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																															
	ADDRESS		Av. de Neptuno		Registry data			R.C. Corrosion			Cracking pattern			Defect in giuntion and detachment			Component deformation			Plaster or finiscing decay																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																															
					Total area: 7488 m²			Cod	Ox1	Ox2	Ox3	Cr1	Cr2	Cr3	Gi1	Gi2	Gi3	Df1	Df2	Df3	De1	De2	De3																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																												
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Decision Support System		Survey output		Building Damage		Criticality		Cracks caused by rebar corrosion			Spalling			Heavy concrete spalling			Thin cracks			Medium cracks			Wide or active cracks			Defects at junction			Detachment of elements			Brick blocks falling down			Component deformation			Excessive deflection or deformations			Walls or elements leaning out of vertical			Decay phenomena (wet area, exfoliation)			Cracking of plaster or veneer			Detachment of plaster or veneer																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																	
Tech. Unit		Element		Sub-element		Cracks caused by rebar corrosion			Spalling			Heavy concrete spalling			Thin cracks			Medium cracks			Wide or active cracks			Defects at junction			Detachment of elements			Brick blocks falling down			Component deformation			Excessive deflection or deformations			Walls or elements leaning out of vertical			Decay phenomena (wet area, exfoliation)			Cracking of plaster or veneer			Detachment of plaster or veneer																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																			
Code	Type	Code	Typology	CCR	Code	Component	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code</

F18	CITY		Puebla de Farnals		MATRIX OF DAMAGE		Cod Type	Ox			Cr			Gi			Df			De			
	ADDRESS		Calle de la Marina		Registry data			R.C. Corrosion			Cracking pattern			Defect in giuntion and detachment			Component deformation			Plaster or finiscing decay			
					Total area: 3040 m²			Cod	Ox1	Ox2	Ox3	Cr1	Cr2	Cr3	Gi1	Gi2	Gi3	Df1	Df2	Df3	De1	De2	De3
					Nº of Floors: 8																		
					Area of single floor: 380 m²																		
					Construction typology: R.C.																		
Nº of buildings blocks: 1																							
Building Condition Rating:																							
2.08																							
Tech. Unit		Element		Sub-element		Cracks caused by rebar corrosion			Cracks caused by rebar corrosion			Cracks caused by rebar corrosion			Cracks caused by rebar corrosion			Cracks caused by rebar corrosion					
Code	Type	Code	Typology	CCR	Code	Component	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code		
S	Str.	S2	Structural element	0.00	S2.2	Column																	
				0.34	S2.3	Beam																	
L	Load b.	L1	Slab	2.23	L1.4	Balcony or projection			3											10			
		L2	Connection	0.00	L2.1	Staircase														34			
N	Non load bearing	N1	Facade envelope	0.29	N1.1	Curtain wall														20			
				0.00	N1.2	Windows fixture																	
		N2	External wall	0.00	N2.1	External R.C. wall																	
				0.00	N2.2	External brick wall																	
		N4	Other	0.00	N4.1	Joint between elements																	

[illegible]

F22	CITY		Puebla de Farnals		MATRIX OF DAMAGE		Cod	Ox			Cr			Gi			Df			De																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																			
	ADDRESS		Carrera de Lepanto		Registry data			R.C. Corrosion			Cracking pattern			Defect in giuntion and detachment			Component deformation			Plaster or finishing decay																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																			
			Total area: 8240 m² Nº of Floors: 8 Area of single floor: 1030 m² Construction typology: R.C. Nº of buildings blocks: 1 Building Condition Rating: 1.8		Macro Type			Cracks caused by rebar corrosion			Spalling			Heavy concrete spalling			Thin cracks			Medium cracks			Wide or active cracks																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																
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F23	CITY		Puebla de Farnals		MATRIX OF DAMAGE		Cod	Ox			Cr			Gi			Df			De																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																						
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					Total area: 3138 m²			Macro Type	Cracks caused by rebar corrosion			Spalling			Heavy concrete spalling			Thin cracks			Medium cracks			Wide or active cracks			Defects at junction			Detachment of elements			Brick blocks falling down			Component deformation			Excessive deflection or deformations			Walls or elements leaning out of vertical			Decay phenomena (wet area, exfoliation)			Cracking of plaster or veneer			Detachment of plaster or veneer																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																							
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F24	CITY		Puebla de Farnals		MATRIX OF DAMAGE		Cod	Ox			Cr			Gi			Df			De																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																	
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					Total area: 13640 m²			Cracks caused by rebar corrosion			Spalling			Heavy concrete spalling			Thin cracks			Medium cracks			Wide or active cracks			Defects at junction			Detachment of elements			Brick blocks falling down			Component deformation			Excessive deflection or deformations			Walls or elements leaning out of vertical			Decay phenomena (wet area, exfoliation)			Cracking of plaster or veneer			Detachment of plaster or veneer																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																			
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F35	CITY		Puebla de Famals		MATRIX OF DAMAGE		Cod Type	Ox			Cr			Gi			Df			De																				
	ADDRESS		Calle de Maestrat		Registry data			R.C. Corrosion			Cracking pattern			Defect in giuntion and detachment			Component deformation			Plaster or finiscing decay																				
					Total area: 2750 m² Nº of Floors: 11 Area of single floor: 250 m² Construction typology: R.C. Nº of buildings blocks: 1 Building Condition Rating: 0.26			Cracks caused by rebar corrosion			Cracking pattern			Defects at junction			Detachment of elements			Brick blocks falling down			Component deformation			Excessive deflection or deformations			Walls or elements leaning out of vertical			Decay phenomena (wet area, exfoliation)			Cracking of plaster or veneer			Detachment of plaster or veneer		
								Ox1	Ox2	Ox3	Cr1	Cr2	Cr3	Gi1	Gi2	Gi3	Df1	Df2	Df3	De1	De2	De3																		
Decision Support System	Survey output						Building Damage		Criticality																															
Tech. Unit		Element				Sub-element																																		
Code	Type	Code	Typology	CCr	Code	Component																																		
S	Str	S2	Structural element	0.00	S2.2	Column																																		
				0.00	S2.3	Beam																																		
L	Load b.	L1	Slab	0.00	L1.4	Balcony or projection																																		
		L2	Connection	0.00	L2.1	Staircase																																		
N	Non load bearing	N1	Facade envelope	0.20	N1.1	Curtain wall																																		
				0.00	N1.2	Windows fixture																																		
		N2	External wall	0.00	N2.1	External R.C. wall																																		
				0.00	N2.2	External brick wall																																		
		N4	Other	0.00	N4.1	Joint between elements																																		

F36	CITY		Puebla de Famals		MATRIX OF DAMAGE		Cod Type	Ox			Cr			Gi			Co			De																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																										
	ADDRESS		Av. de Neptuno		Registry data			R.C. Corrosion			Cracking pattern			Defect in giuntion and detachment			Corrosion			Plaster or finiscing decay																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																										
					Total area: 11600 m² Nº of Floors: 16 Area of single floor: 725 m² Construction typology: R.C. Nº of buildings blocks: 1 Building Condition Rating: 1.66			Cracks caused by rebar corrosion			Spalling			Heavy concrete spalling			Thin cracks			Medium cracks			Wide or active cracks			Defects at junction			Detachment of elements			Brick blocks falling down			Corrosion of steel element			Yielding			Corrosion with section reduction			Decay phenomenon (wet area, exfoliation)			Cracking of plaster or veneer			Detachment of plaster or veneer																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																												
								Ox1	Ox2	Ox3	Cr1	Cr2	Cr3	Gi1	Gi2	Gi3	Cs1	Cs2	Cs3	De1	De2	De3																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																								
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F37		CITY		Puebla de Famals		MATRIX OF DAMAGE		Cod Type	Ox			Cr			Gi			Df			De																			
		ADDRESS		Calle de la Marina		Registry data			R.C. Corrosion			Cracking pattern			Defect in giuntion and detachment			Component deformation			Plaster or finiscing decay																			
Decision Support System	Survey output			Total area: 4600 m ² Nº of Floors: 10 Area of single floor: 460 m ² Construction typology: R.C. Nº of buildings blocks: 1 Building Condition Rating: 1.43		Building Damage Criticality	Cracks caused by rebar corrosion			Cracking pattern			Defects at junction			Detachment of elements			Brick blocks falling down			Component deformation			Excessive deflection or deformations			Walls or elements leaning out of vertical			Decay phenomenon (wet area, exfoliation)			Cracking of plaster or veneer			Detachment of plaster or veneer			
							Ox1		Ox2	Ox3	Cr1	Cr2	Cr3	Gi1	Gi2	Gi3	Df1	Df2	Df3	De1	De2	De3																		
		Tech. Unit		Element		Sub-element																																		
		Code	Type	Code	Typology	CCr	Code	Component																																
S	Str.	S2	Structural element	0.00	S2.2	0.18	S2.3	Column																																
L	Load b.	L1	Slab	1.35	L1.4	0.00	L1.1	Balcony or projection																																
		L2	Connection		L2.1		Staircase																																	
N	Non load bearing	N1	Facade envelope	0.31	N1.1	0.00	N1.2	Curtain wall																																
								N1.2	Windows fixture																															
		N2	External wall	0.00	N2.1	0.00	N2.2	External R.C. wall																																
								N2.2	External brick wall																															
		N4	Other	0.00	N4.1		N4.1	Joint between elements																																

F28	CITY		Puebla de Farnals		MATRIX OF DAMAGE		Cod	Ox			Cr			Gi			Df			De																																
	ADDRESS		Av. de Neptuno		Registry data			R.C. Corrosion			Cracking pattern			Defect in giuntion and detachment			Component deformation			Plaster or finising decay																																
					Total area: 6000 m²			Ox1 Ox2 Ox3			Cr1 Cr2 Cr3			Gi1 Gi2 Gi3			Df1 Df2 Df3			De1 De2 De3																																
					Nº of Floors: 10			Cracks caused by rebar corrosion			Spalling			Heavy concrete spalling			Thin cracks			Medium cracks			Wide or active cracks			Defects at junction			Detachment of elements			Brick blocks falling down			Component deformation			Excessive deflection or deformations			Walls or elements leaning out of vertical			Decay phenomena (wet area, exfoliation)			Cracking of plaster or veneer			Detachment of plaster or veneer		
					Area of single floor: 460 m²																																															
Construction typology: R.C.																																																				
		Nº of buildings blocks:																																																		
		Building Condition Rating:																																																		
		1.05																																																		
Tech. Unit		Element		Sub-element																																																
Code	Type	Code	Typology	CCr	Code	Component																																														
S	Str.	S2	Structural element	0.00	S2.2	Column																																														
				0.17	S2.3	Beam				3																																										
L	Load b.	L1	Slab	1.13	L1.4	Balcony or projection																																														
		L2	Connection	0.00	L2.1	Staircase																																														
N	Non load bearing	N1	Facade envelope	0.14	N1.1	Curtain wall																																														
				0.00	N1.2	Windows fixture																																														
		N2	External wall	0.00	N2.1	External R.C. wall																																														
				0.00	N2.2	External brick wall																																														
		N4	Other	0.00	N4.1	Joint between elements																																														

F29	CITY		Puebla de Farnals		MATRIX OF DAMAGE		Cod	Ox			Cr			Gi			Df			De												
	ADDRESS		Calle de Carabelas		Registry data			R.C. Corrosion			Cracking pattern			Defect in giuntion and detachment			Component deformation			Plaster or finising decay												
					Total area: 2400 m ² N° of Floors: 8 Area of single floor: 300 m ² Construction typology: R.C. N° of buildings blocks: Building Condition Rating: 			Ox1 Ox2 Ox3			Cr1 Cr2 Cr3			Gi1 Gi2 Gi3			Df1 Df2 Df3			De1 De2 De3												
								Cracks caused by rebar corrosion			Spalling			Heavy concrete spalling			Thin cracks			Medium cracks			Wide or active cracks									
								Defects at junction			Detachment of elements			Brick blocks falling down			Component deformation			Excessive deflection or deformations			Walls or elements leaning out of vertical			Decay phenomena (wet area, exfoliation)			Cracking of plaster or veneer			Detachment of plaster or veneer
Tech. Unit							Element		Sub-element																							
Code	Type	Code	Typology	CCr	Code	Component																										
S	Str.	S2	Structural element	0.00	S2.2	Column																										
				0.00	S2.3	Beam																										
L	Load b.	L1	Slab	0.00	L1.4	Balcony or projection																										
		L2	Connection	0.00	L2.1	Staircase																										
N	Non load bearing	N1	Facade envelope	0.06	N1.1	Curtain wall																2										
				0.00	N1.2	Windows fixture																										
		N2	External wall	0.00	N2.1	External R.C. wall																										
				0.00	N2.2	External brick wall																										
		N4	Other	0.00	N4.1	Joint between elements																										

F30	CITY		Puebla de Farnals		MATRIX OF DAMAGE		Cod	Ox			Cr			Gi			Df			De																																
	ADDRESS		Calle de la Ribera		Registry data			R.C. Corrosion			Cracking pattern			Defect in giuntion and detachment			Component deformation			Plaster or finising decay																																
					Total area: 7920 m²			Ox1 Ox2 Ox3			Cr1 Cr2 Cr3			Gi1 Gi2 Gi3			Df1 Df2 Df3			De1 De2 De3																																
					Nº of Floors: 11			Cracks caused by rebar corrosion			Spalling			Heavy concrete spalling			Thin cracks			Medium cracks			Wide or active cracks			Defects at junction			Detachment of elements			Brick blocks falling down			Component deformation			Excessive deflection or deformations			Walls or elements leaning out of vertical			Decay phenomena (wet area, exfoliation)			Cracking of plaster or veneer			Detachment of plaster or veneer		
					Area of single floor: 720 m²																																															
					Construction typology: R.C.																																															
Nº of buildings blocks: 2																																																				
Building Condition Rating:		1.25																																																		
Tech. Unit		Element		Sub-element																																																
Code	Type	Code	Typology	CCr	Code	Component																																														
S	Str.	S2	Structural element	0.00	S2.2	Column																																														
				0.00	S2.3	Beam																																														
L	Load b.	L1	Slab	2.24	L1.4	Balcony or projection	9															21			15																											
		L2	Connection	0.00	L2.1	Staircase																																														
N	Non load bearing	N1	Facade envelope	0.29	N1.1	Curtain wall																16																														
				0.00	N1.2	Windows fixture																																														
		N2	External wall	0.00	N2.1	External R.C. wall																																														
				0.00	N2.2	External brick wall																																														
			N4	Other	0.00	N4.1	Joint between elements																																													

F34	CITY		Puebla de Famals		MATRIX OF DAMAGE		Cod Macro Type	Ox			Cr			Gi			Df			De																			
	ADDRESS		Av. de la Constitución		Registry data			R.C. Corrosion			Cracking pattern			Defect in giuntion and detachment			Component deformation			Plaster or finising decay																			
			Total area: 11250 m²		Nº of Floors: 9			Area of single floor: 1250 m²			Construction typology: R.C.			Nº of buildings blocks: 1			Building Condition Rating:																						
			0.14																																				
Decision Support System Survey output						Building Damage		Criticality	Cracks caused by rebar corrosion			Spalling		Heavy concrete spalling		Thin cracks		Medium cracks		Wide or active cracks		Defects at junction		Detachment of elements		Brick blocks falling down		Component deformation		Excessive deflection or deformations		Walls or elements leaning out of vertical		Decay phenomena (wet area, exfoliation)		Cracking of plaster or veneer		Detachment of plaster or veneer	
Tech. Unit		Element		Sub-element																																			
Code	Type	Code	Typology	CCr	Code	Component																																	
S	Str.	S2	Structural element	0.00	S2.2	Column																																	
				0.00	S2.3	Beam																																	
L	Load b.	L1	Slab	0.00	L1.4	Balcony or projection																																	
		L2	Connection	0.00	L2.1	Staircase																																	
N	Non load bearing	N1	Facade envelope	0.09	N1.1	Curtain wall																																	
				0.00	N1.2	Windows fixture																																	
		N2	External wall	0.00	N2.1	External R.C. wall																																	
				0.00	N2.2	External brick wall																																	
		N4	Other	0.00	N4.1	Joint between elements																																	

F35	CITY		Puebla de Famals		MATRIX OF DAMAGE		Cod Macro Type	Ox			Cr			Gi			Df			De																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																							
	ADDRESS		Calle el Alcoià		Registry data			R.C. Corrosion			Cracking pattern			Defect in giuntion and detachment			Component deformation			Plaster or finising decay																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																							
			Total area: 5720 m²		Nº of Floors: 13			Thin cracks			Medium cracks			Wide or active cracks			Defects at junction			Detachment of elements			Brick blocks falling down			Component deformation			Excessive deflection or deformations			Walls or elements leaning out of vertical			Decay phenomena (wet area, exfoliation)			Cracking of plaster or veneer			Detachment of plaster or veneer																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																		
			Area of single floor: 440 m²		Construction typology: R.C.																																							Nº of buildings blocks: 1		Building Condition Rating: 1.19																																																																																																																																																																																																																																																																																																																																																																																																																																																																																													
Decision Support System Survey output								Cracks caused by rebar corrosion		Spalling		Heavy concrete spalling																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																															
Tech. Unit		Element				Sub-element																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																					
Code	Type	Code	Typology		CCr	Code	Component																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																				
S	Str.	S2	Structural element		0.57	S2.2	Column		11																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																		
					0.24	S2.3																																Beam																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																					

F36	CITY		Puebla de Famals		MATRIX OF DAMAGE		Cod Macro Type	Ox			Cr			Gi			Df			De																			
	ADDRESS		Av. de la Constitucion		Registry data			R.C. Corrosion			Cracking pattern			Defect in giuntion and detachment			Component deformation			Plaster or finising decay																			
			Total area: 6860 m²		Nº of Floors: 7			Area of single floor: 980 m²			Construction typology: R.C.			Nº of buildings blocks: 3			Building Condition Rating:																						
					0.03																																		
Decision Support System Survey output						Building Damage		Criticality	Cracks caused by rebar corrosion			Spalling		Heavy concrete spalling		Thin cracks		Medium cracks		Wide or active cracks		Defects at junction		Detachment of elements		Brick blocks falling down		Component deformation		Excessive deflection or deformations		Walls or elements leaning out of vertical		Decay phenomena (wet area, exfoliation)		Cracking of plaster or veneer		Detachment of plaster or veneer	
Tech. Unit		Element		Sub-element					corrosion																														
Code	Type		Typology	CCr	Code	Component																																	
S	Str.	S2	Structural element	0.00	S2.2	Column																																	
				0.00	S2.3	Beam																																	
L	Load b.	L1	Slab	0.00	L1.4	Balcony or projection																																	
				0.00	L2.1	Staircase																																	
N	Non load bearing	N1	Facade envelope	0.04	N1.1	Curtain wall																																	
				0.00	N1.2	Windows fixture																																	
		N2	External wall	0.00	N2.1	External R.C. wall																																	
				0.00	N2.2	External brick wall																																	
		0.00	N4.1	Joint between elements																																			

F37	CITY		Puebla de Farnals		MATRIX OF DAMAGE		Cod	Ox			Cr			Gi			Df			De		
	ADDRESS		Calle de la Val d'Albaida		Registry data			R.C. Corrosion			Cracking pattern			Defect in giuntion and detachment			Component deformation			Plaster or finising decay		
			Total area: 2800 m ²		Building Damage			Cracks caused by rebar corrosion			Thin cracks			Detachment of elements			Component deformation			Cracking of plaster or veneer		
			Nº of Floors: 7					Spalling			Medium cracks			Excessive deflection or deformations			Detachment of plaster or veneer					
Area of single floor: 400 m ²			Heavy concrete spalling				Wide or active cracks			Walls or elements leaning out of vertical			Decay phenomena (wet area, exfoliation)									
		Construction typology: R.C.		Nº of buildings blocks: 2																		
		Building Condition Rating:		0.08																		

F38	CITY		Puebla de Farnals		MATRIX OF DAMAGE		Cod	Ox			Cr			Gi			Df			De		
	ADDRESS		Avenida del Mar		Registry data			R.C. Corrosion			Cracking pattern			Defect in giuntion and detachment			Component deformation			Plaster or finising decay		
	Decision Support System Survey output 		Total area: 3010 m ²		Building Damage Criticality Cracks caused by rebar corrosion Spalling Heavy concrete spalling Thin cracks Medium cracks Wide or active cracks Defects at junction Detachment of elements Brick blocks falling down Component deformation Excessive deflection or deformations Walls or elements leaning out of vertical Decay phenomena (wet area, exfoliation) Cracking of plaster or veneer Detachment of plaster or veneer			Ox1	Ox2	Ox3	Cr1	Cr2	Cr3	Gi1	Gi2	Gi3	Df1	Df2	Df3	De1	De2	De3
N° of Floors: 7																						
Area of single floor: 430 m ²																						
Construction typology: R.C.																						
		N° of buildings blocks: 3																				
		Building Condition Rating:																				
		1.21																				
Tech. Unit		Element		Sub-element																		
Code	Type	Code	Typology	CCr	Code	Component																
S	Str.	S2	Structural element	0.00	S2.2	Column																
				0.00	S2.3	Beam																
L	Load b.	L1	Slab	0.00	L1.4	Balcony or projection																
		L2	Connection	0.00	L2.1	Staircase																
N	Non load bearing	N1	Facade envelope	0.81	N1.1	Curtain wall																
				0.00	N1.2	Windows fixture																
		N2	External wall	0.00	N2.1	External R.C. wall																
				0.00	N2.2	External brick wall																
		N4	Other	0.00	N4.1	Joint between elements																

F39	CITY		Puebla de Farnals		MATRIX OF DAMAGE		Cod	Ox			Cr			Gi			Df			De																																		
	ADDRESS		Calle el Alcoia		Registry data			R.C. Corrosion			Cracking pattern			Defect in giuntion and detachment			Component deformation			Plaster or finising decay																																		
			Total area: 2870 m² Nº of Floors: 7 Area of single floor: 430 m² Construction typology: R.C. Nº of buildings blocks: 3 Building Condition Rating: 0.08		Building Damage			Cracks caused by rebar corrosion			Cracking pattern			Defect in giuntion and detachment			Component deformation			Plaster or finising decay																																		
					Criticality			Spalling			Heavy concrete spalling			Thin cracks			Medium cracks			Wide or active cracks			Defects at junction			Detachment of elements			Brick blocks falling down			Component deformation			Excessive deflection or deformations			Walls or elements leaning out of vertical			Decay phenomena (wet area, exfoliation)			Cracking of plaster or veneer			Detachment of plaster or veneer							
Tech. Unit		Element				Sub-element				Ox1			Ox2			Ox3			Cr1			Cr2			Cr3			Gi1			Gi2			Gi3			Df1			Df2			Df3			De1			De2			De3		
Code	Type	Code	Typology		CCr	Code	Component																																															
S	Str.	S2	Structural element		0.00	S2.2	Column																																															
					0.00	S2.3	Beam																																															
L	Load b.	L1	Slab		0.02	L1.4	Balcony or projection																																															
		L2	Connection		0.00	L2.1	Staircase																																															
N	Non load bearing	N1	Facade envelope		0.06	N1.1	Curtain wall																																															
					0.00	N1.2	Windows fixture																																															
		N2	External wall		0.00	N2.1	External R.C. wall																																															
					0.00	N2.2	External brick wall																																															
		N4	Other		0.00	N4.1	Joint between elements																																															

F40	CITY		Puebla de Farnals		MATRIX OF DAMAGE		Cod	Ox			Cr			Gi			Df			De												
	ADDRESS		Avenida del Mar		Registry data			R.C. Corrosion			Cracking pattern			Defect in giuntion and detachment			Component deformation			Plaster or finiscing decay												
					Total area: 2800 m ²			Ox1	Ox2	Ox3	Cr1	Cr2	Cr3	Gi1	Gi2	Gi3	Df1	Df2	Df3	De1	De2	De3										
					Nº of Floors: 7																											
Decision Support System		Survey output		Building Damage		Criticality		Cracks caused by rebar corrosion			Spalling			Heavy concrete spalling			Thin cracks			Medium cracks												
Tech. Unit		Element		Sub-element		Component		Wide or active cracks			Defects at junction			Detachment of elements			Brick blocks falling down			Component deformation												
Code	Type	Code	Typology	CCR	Code	Code	Code	Excessive deflection or deformations			Walls or elements leaning out of vertical			Decay phenomena (wet area, exfoliation)			Cracking of plaster or veneer			Detachment of plaster or veneer												
S	Str.	S2	Structural element	0.00	S2.2	Column																										
				0.00	S2.3	Beam																										
L	Load b.	L1	Slab	0.06	L1.4	Balcony or projection													4													
		L2	Connection	0.00	L2.1	Staircase																										
N	Non load bearing	N1	Facade envelope	0.02	N1.1	Curtain wall													2													
				0.00	N1.2	Windows fixture																										
		N2	External wall	0.00	N2.1	External R.C. wall																										
				0.00	N2.2	External brick wall																										
		N4	Other	0.00	N4.2	Joint between elements																										

F41		CITY		Puebla de Farnals		MATRIX OF DAMAGE		Cod	Ox			Cr			Gi			Df			De																																
		ADDRESS		Avenida del Mar		Registry data			R.C. Corrosion			Cracking pattern			Defect in giuntion and detachment			Component deformation			Plaster or finiscing decay																																
Decision Support System	Survey output			Total area: 2940 m² Nº of Floors: 7 Area of single floor: 420 m² Construction typology: R.C. Nº of buildings blocks: 3 Building Condition Rating: 0.08		Building Damage	Criticality		Cracks caused by rebar corrosion			Spalling			Heavy concrete spalling			Thin cracks			Medium cracks																																
									Ox1			Ox2			Ox3			Cr1			Cr2			Cr3			Gi1			Gi2			Gi3			Df1			Df2			Df3			De1			De2			De3		
Tech. Unit		Element		Sub-element		Component		Cracks caused by rebar corrosion			Spalling			Heavy concrete spalling			Thin cracks			Medium cracks			Wide or active cracks			Defects at junction			Detachment of elements			Brick blocks falling down			Component deformation			Excessive deflection or deformations			Walls or elements leaning out of vertical			Decay phenomena (wet area, exfoliation)			Cracking of plaster or veneer			Detachment of plaster or veneer			
Code	Type	Code	Typology	CCR	Code	Code	Code																																														
S	Str.	S2	Structural element	0.00	S2.2		Column																																														
				0.00	S2.3		Beam																																														
L	Load b.	L1	Slab	0.06	L1.4		Balcony or projection																																														
		L2	Connection	0.00	L2.1		Staircase																																														
N	Non load bearing	N1	Facade envelope	0.00	N1.1		Curtain wall																																														
				0.00	N1.2		Windows fixture																																														
		N2	External wall	0.00	N2.1		External R.C. wall																																														
				0.00	N2.2		External brick wall																																														
		N4	Other	0.00	N4.1		Joint between elements																																														

F42	CITY		Puebla de Farnals		MATRIX OF DAMAGE		Cod	Ox			Cr			Gi			Df			De												
	ADDRESS		Calle Caravalles		Registry data			R.C. Corrosion			Cracking pattern			Defect in giuntion and detachment			Component deformation			Plaster or finiscing decay												
					Total area: 2700 m ²			Ox1	Ox2	Ox3	Cr1	Cr2	Cr3	Gi1	Gi2	Gi3	Df1	Df2	Df3	De1	De2	De3										
					Nº of Floors: 6																											
Decision Support System		Survey output		Building Damage		Criticality		Cracks caused by rebar corrosion			Spalling			Heavy concrete spalling			Thin cracks			Medium cracks												
Tech. Unit		Element		Sub-element		Wide or active cracks					Defects at junction			Detachment of elements			Brick blocks falling down			Component deformation												
Code	Type	Code	Typology	CCR	Code	Code	Code	Excessive deflection or deformations			Walls or elements leaning out of vertical			Decay phenomena (wet area, exfoliation)			Cracking of plaster or veneer			Detachment of plaster or veneer												
S	Str.	S2	Structural element	0.00	S2.2	Column																										
				0.00	S2.3	Beam																										
L	Load b.	L1	Slab	1.41	L1.4	Balcony or projection													15													
		L2	Connection	0.00	L2.1	Staircase																										
N	Non load bearing	N1	Facade envelope	0.26	N1.1	Curtain wall													16													
				0.00	N1.2	Windows fixture																										
		N2	External wall	0.00	N2.1	External R.C. wall																										
				0.00	N2.2	External brick wall																										
		N4	Other	0.00	N4.1	Joint between elements																										

I43		CITY		Puebla de Farnals		MATRIX OF DAMAGE		Cod Macro type	Ox			Cr			Gi			Df			De				
		ADDRESS		Calle Caravalles		Registry data			R.C. Corrosion			Cracking pattern			Defect in giuntion and detachment			Component deformation			Plaster or finishing decay				
Decision Support System						Total area: 2700 m²			Building Damage	Cod	Ox1	Ox2	Ox3	Cr1	Cr2	Cr3	Gi1	Gi2	Gi3	Df1	Df2	Df3	De1	De2	De3
						Nº of Floors: 6																			
						Area of single floor: 450 m²																			
						Construction typology: R.C.																			
						Nº of buildings blocks: 3																			
						Building Condition Rating:																			
						1.06																			
Tech. Unit		Element		Sub-element				Cracks caused by rebar corrosion			Spalling			Heavy concrete spalling			Thin cracks			Medium cracks					
Code	Type	Code	Typology	CCr	Code	Component	Wide or active cracks			Defects at junction			Detachment of elements			Brick blocks falling down			Component deformation						
S	Str.	S2	Structural element	0.00	S2.2	Column																			
				0.00	S2.3	Beam																			
L	Load b.	L1	Slab	1.41	L1.4	Balcony or projection																			
		L2	Connection	0.00	L2.1	Staircase													6						
N	Non load bearing	N1	Facade envelope	0.26	N1.1	Curtain wall																			
				0.00	N1.2	Windows fixture										6									
		N2	External wall	0.00	N2.1	External R.C. wall																			
				0.00	N2.2	External brick wall																			
		N4	Other	0.00	N4.1	Joint between elements																			

I44		CITY		Puebla de Farnals		MATRIX OF DAMAGE		Cod Macro type	Ox			Cr			Gi			Df			De																															
		ADDRESS		Calle Caravalles		Registry data			R.C. Corrosion			Cracking pattern			Defect in giuntion and detachment			Component deformation			Plaster or finishing decay																															
Decision Support System Survey output			Total area: 2700 m² Nº of Floors: 6 Area of single floor: 450 m² Construction typology: R.C. Nº of buildings blocks: 3 Building Condition Rating: 1.08		Building Damage Criticality		Cracks caused by rebar corrosion			Spalling			Heavy concrete spalling			Thin cracks			Medium cracks			Wide or active cracks			Defects at junction			Detachment of elements			Brick blocks falling down			Component deformation			Excessive deflection or deformations			Walls or elements leaning out of vertical			Decay phenomena (wet area, exfoliation)			Cracking of plaster or veneer			Detachment of plaster or veneer			
							Ox1		Ox2	Ox3	Cr1	Cr2	Cr3	Gi1	Gi2	Gi3	Df1	Df2	Df3	De1	De2	De3																														
Tech. Unit		Element		Sub-element																																																
Code	Type	Code	Typology	CCr	Code	Component																																														
S	Str.	S2	Structural element	0.00	S2.2	Column																																														
				0.00	S2.3	Beam																																														
L	Load b.	L1	Slab	0.56	L1.4	Balcony or projection																																														
		L2	Connection	0.00	L2.1	Staircase																																														
N	Non load bearing	N1	Facade envelope	0.09	N1.1	Curtain wall																																														
				0.00	N1.2	Windows fixture																																														
		N2	External wall	0.00	N2.1	External R.C. wall																																														
				0.00	N2.2	External brick wall																																														
		N4	Other	0.00		Joint between elements																																														

I45		CITY		Puebla de Farnals		MATRIX OF DAMAGE		Cod Macro type	Ox			Cr			Gi			Df			De																																	
		ADDRESS		Calle Caravalles		Registry data			R.C. Corrosion			Cracking pattern			Defect in giuntion and detachment			Component deformation			Plaster or finishing decay																																	
Decision Support System	Survey output			Total area: 2700 m² Nº of Floors: 6 Area of single floor: 450 m² Construction typology: R.C. Nº of buildings blocks: 3 Building Condition Rating: 1.1		Cracks caused by rebar corrosion			Spalling			Heavy concrete spalling			Thin cracks			Medium cracks			Wide or active cracks																																	
						Ox1			Ox2			Ox3			Cr1			Cr2			Cr3			Gi1			Gi2			Gi3			Df1			Df2			Df3			De1			De2			De3						
Tech. Unit		Element		Sub-element																																																		
Code	Type	Code	Typology	CCr	Code	Component																																																
S	Str.	S2	Structural element	0.00	S2.2	Column																																																
				0.00	S2.3	Beam																																																
L	Load b.	L1	Slab	1.70	L1.4	Balcony or projection																																																
				0.00	L2.1	Staircase																																																
N	Non load bearing	N1	Facade envelope	0.23	N1.1	Curtain wall																																																
				0.00	N1.2	Windows fixture																																																
				0.00	N2.1	External R.C. wall																																																
				0.00	N2.2	External brick wall																																																
				0.00	N4.1	Joint between elements																																																

F-49		CITY		Puebla de Famals		MATRIX OF DAMAGE		Cod Metric Cod	Ox			Cr			Gi			Df			De																																
		ADDRESS		Calle Carvalles		Registry data			R.C. Corrosion			Cracking pattern			Defect in giuntion and detachment			Component deformation			Plaster or finishing decay																																
Decision Support System Survey output				Total area: 2700 m² Nº of Floors: 6 Area of single floor: 450 m² Construction typology: R.C. Nº of buildings blocks: 3 Building Condition Rating: 2.66			Building Damage Criticality		Cracks caused by rebar corrosion			Spalling			Heavy concrete spalling			Thin cracks			Medium cracks			Wide or active cracks			Defects at junction			Detachment of elements			Brick blocks falling down			Component deformation			Excessive deflection or deformations			Walls or elements leaning out of vertical			Decay phenomena (wet area, exfoliation)			Cracking of plaster or veneer			Detachment of plaster or veneer		
									Ox1	Ox2	Ox3	Cr1	Cr2	Cr3	Gi1	Gi2	Gi3	Df1	Df2	Df3	De1	De2	De3																														
Tech. Unit		Element				Sub-element																																															
Code	Type	Code	Typology		CCr	Code	Component																																														
S	Str.	S2	Structural element		0.00	S2.2	Column Beam		12				6									2																															
					0.90	S2.3																																															
L	Load b.	L1	Slab		1.41	L1.4	Balcony or projection																																														
		L2	Connection		0.00	L2.1	Staircase																																														
N	Non load bearing	N1	Facade envelope		0.39	N1.1	Curtain wall																																														
					0.00	N1.2	Windows fixture																																														
		N2	External wall		0.00	N2.1	External R.C. wall																																														
					0.00	N2.2	External brick wall																																														
		N4	Other		0.00	N4.1	Joint between elements																																														

F-50	CITY		Puebla de Famals		MATRIX OF DAMAGE		Cool Type	Ox			Cr			Gi			Df			De																							
	ADDRESS		Calle Carvalles		Registry data			R.C. Corrosion			Cracking pattern			Defect in giuntion and detachment			Component deformation			Plaster or finishing decay																							
					Total area: 2700 m² Nº of Floors: 6 Area of single floor: 450 m² Construction typology: R.C. Nº of buildings blocks: 3 Building Condition Rating: 1.34			Cracks caused by rebar corrosion			Cracking pattern			Defects at junction			Component deformation			Decay phenomena (wet area, exfoliation)																							
								Ox1	Ox2	Ox3	Cr1	Cr2	Cr3	Gi1	Gi2	Gi3	Df1	Df2	Df3	De1	De2	De3																					
Decision Support System		Survey output		Building Damage		Criticality		Spalling			Heavy concrete spalling			Thin cracks			Medium cracks			Wide or active cracks			Detachment of elements			Brick blocks falling down			Component deformation			Excessive deflection or deformations			Walls or elements leaning out of vertical			Cracking of plaster or veneer			Detachment of plaster or veneer		
Tech. Unit		Element		Sub-element																																							
Code	Type	Code	Typology	CCr	Code	Component																																					
S	Str.	S2	Structural element	0.00	S2.2	Column																																					
				0.00	S2.3	Beam																																					
L	Load b.	L1	Slab	1.69	L1.4	Balcony or projection																																					
		L2	Connection	0.00	L2.1	Staircase																																					
N	Non load bearing	N1	Facade envelope	0.33	N1.1	Curtain wall																																					
				0.00	N1.2	Windows fixture																																					
		N2	External wall	0.00	N2.1	External R.C. wall																																					
				0.00	N2.2	External brick wall																																					
		N4	Other	0.00	N4.1	Joint between elements																																					

F51	CITY		Puebla de Famals		MATRIX OF DAMAGE		Cool Type	Ox			Cr			Gi			Df			De		
	ADDRESS		Calle Carvalles		Registry data			R.C. Corrosion			Cracking pattern			Defect in giuntion and detachment			Component deformation			Plaster or finishing decay		
					Total area: 2700 m ² Nº of Floors: 6 Area of single floor: 450 m ² Construction typology: R.C. Nº of buildings blocks: 3 Building Condition Rating: 2.66			Ox1	Ox2	Ox3	Cr1	Cr2	Cr3	Gi1	Gi2	Gi3	Df1	Df2	Df3	De1	De2	De3
								Cracks caused by rebar corrosion	Spalling	Heavy concrete spalling	Thin cracks	Medium cracks	Wide or active cracks	Defects at junction	Detachment of elements	Brick blocks falling down	Component deformation	Excessive deflection or deformations	Walls or elements leaning out of vertical	Decay phenomena (wet area, exfoliation)	Cracking of plaster or veneer	Detachment of plaster or veneer
Tech. Unit		Element		Sub-element																		
Code	Type	Code	Typology	CCr	Code	Component																
S	Str.	S2	Structural element	0.00	S2.2	Column																
				0.90	S2.3	Beam	12				6						2					
L	Load b.	L1	Slab	1.42	L1.4	Balcony or projection													15			
		L2	Connection	0.00	L2.1	Staircase																
N	Non load bearing	N1	Facade envelope	0.39	N1.1	Curtain wall																
				0.00	N1.2	Windows fixture													24			
		N2	External wall	0.00	N2.1	External R.C. wall																
				0.00	N2.2	External brick wall																
		N4	Other	0.00	N4.1	Joint between elements																

F3	CITY		Pueblo de Farnals		MATRIX OF DAMAGE		Macro Type	Ox			Cr			Gi			Df			De																															
	ADDRESS		Avenida del Mar		Registry data			R.C. Corrosion			Cracking pattern			Defect in giuntion and detachment			Component deformation			Plaster or finisning decay																															
			Total area: 2700 m²		Cracks caused by rebar corrosion			Spalling			Heavy concrete spalling			Thin cracks			Medium cracks			Wide or active cracks			Defects at junction			Detachment of elements			Brick blocks falling down			Component deformation			Excessive deflection or deformations			Walls or elements leaning out of vertical			Decay phenomena (wet area, exfoliation)			Cracking of plaster or veneer			Detachment of plaster or veneer				
			Nº of Floors: 6																																																
			Area of single floor: 450 m²																																																
Construction typology: R.C.																																																			
		Nº of buildings blocks: 3																																																	
		Building Condition Rating:																																																	
		1.2																																																	

Tech. Unit		Element			Sub-element		
Code	Type	Code	Typology	CCr	Code	Component	
S	Str.	S2	Structural element	0.00	S2.2	Column	
				0.00	S2.3	Beam	
L	Load b.	L1	Slab	1.43	L1.4	Balcony or projection	
				0.00	L2.1	Staircase	
N	Non load bearing	N1	Facade envelope	0.33	N1.1	Curtain wall	
				0.00	N1.2	Windows fixture	
		N2	External wall	0.00	N2.1	External R.C. wall	
				0.00	N2.2	External brick wall	
		N4	Other	0.00	N4.1	Joint between elements	

F-3	CITY		Pueblo de Farnals		MATRIX OF DAMAGE		Macro Type	Ox			Cr			Gi			Df			De																					
	ADDRESS		Camino de la Playa		Registry data			R.C. Corrosion			Cracking pattern			Defect in giuntion and detachment			Component deformation			Plaster or finishing decay																					
			Total area: 2700 m ²		Cracks caused by rebar corrosion			Spalling			Thin cracks			Defects at junction			Detachment of elements			Brick blocks falling down			Component deformation			Excessive deflection or deformations			Walls or elements leaning out of vertical			Decay phenomena (wet area, exfoliation)			Cracking of plaster or veneer			Detachment of plaster or veneer			
			Nº of Floors: 6																																						
			Area of single floor: 450 m ²																																						
Construction typology: R.C.																																									
		Nº of buildings blocks: 3		Building Condition Rating: 6.01																																					

Tech. Unit		Element			Sub-element	
Code	Type	Code	Typology	CCr	Code	Component
S	Str.	S2	Structural element	2.14	S2.2	Column
				0.72	S2.3	Beam
L	Load b.	L1	Slab	1.14	L1.4	Balcony or projection
				0.00	L2.1	Staircase
N	Non load bearing	N1	Facade envelope	0.66	N1.1	Curtain wall
				0.00	N1.2	Windows fixture
				0.00	N2.1	External R.C. wall
				0.00	N2.2	External brick wall
				0.00	N4.1	Joint between elements

F-4	Decision Support System Survey output	CITY		Pueblo de Farnals		MATRIX OF DAMAGE		Macro Type	Ox			Cr			Gi			Df			De		
		ADDRESS		Camino de la Playa		Registry data			R.C. Corrosion			Cracking pattern			Defect in giuntion and detachment			Component deformation			Plaster or finishing decay		
				Total area: 2700 m ² Nº of Floors: 6 Area of single floor: 450 m ² Construction typology: R.C. Nº of buildings blocks: 3 Building Condition Rating: 1.2		Cracks caused by rebar corrosion	Spalling		Heavy concrete spalling	Thin cracks	Medium cracks	Wide or active cracks	Defects at junction	Detachment of elements	Brick blocks falling down	Component deformation	Excessive deflection or deformations	Walls or elements leaning out of vertical	Decay phenomena (wet area, exfoliation)	Cracking of plaster or veneer	Detachment of plaster or veneer		
Tech. Unit		Element		Sub-element		Code		Code		Code		Code		Code		Code		Code		Code			
Code	Type	Code	Typology	CCr	Code	Component	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code	Code			
S	Str.	S2	Structural element	0.00	S2.2	Column																	
				0.00	S2.3	Beam																	
L	Load b.	L1	Slab	1.23	L1.4	Balcony or projection													12	2			
		L2	Connection	0.00	L2.1	Staircase																	
				0.00	L2.1	Staircase																	
N	Non load bearing	N1	Facade envelope	0.43	N1.1	Curtain wall													14	2			
				0.00	N1.2	Windows fixture																	
		N2	External wall	0.00	N2.1	External R.C. wall																	
				0.00	N2.2	External brick wall																	
		N4	Other	0.00	N4.1	Joint between elements																	

F5		CITY		Puebla de Farnals		MATRIX OF DAMAGE		Cod	Ox			Cr			Gi			Df			De																																
		ADDRESS		Camino de la Playa		Registry data			R.C. Corrosion			Cracking pattern			Defect in giuntion and detachment			Component deformation			Plaster or finiscing decay																																
Decision Support System	Survey output			Total area: 2700 m ² Nº of Floors: 6 Area of single floor: 450 m ² Construction typology: R.C. Nº of buildings blocks: 3 Building Condition Rating: 1.21		Building Damage	Criticality		Cracks caused by rebar corrosion			Spalling			Heavy concrete spalling			Thin cracks			Medium cracks			Wide or active cracks			Defects at junction			Detachment of elements			Brick blocks falling down			Component deformation			Excessive deflection or deformations			Walls or elements leaning out of vertical			Decay phenomena (wet area, exfoliation)			Cracking of plaster or veneer			Detachment of plaster or veneer		
									Ox1	Ox2	Ox3	Cr1	Cr2	Cr3	Gi1	Gi2	Gi3	Df1	Df2	Df3	De1	De2	De3																														
Tech. Unit		Element				Sub-element																																															
Code	Type	Code	Typology		CCr	Code	Component																																														
S	Str	S2	Structural element		0.00	S2.2	Column																																														
					0.00	S2.3	Beam																																														
L	Load b.	L1	Slab		1.65	L1.4	Balcony or projection																																														
		L2	Connection		0.00	L2.1	Staircase																																														
					0.36	N1.1	Curtain wall																																														
		N1	Facade envelope		0.00	N1.2	Windows fixture																																														
					0.00	N2.1	External R.C. wall																																														
		N2	External wall		0.00	N2.2	External brick wall																																														
					0.00	N4.1	Joint between elements																																														

F6	CITY		Puebla de Farnals		MATRIX OF DAMAGE		Cod	Ox			Cr			Gi			Df			De																								
	ADDRESS		Camino de la Playa		Registry data			R.C. Corrosion			Cracking pattern			Defect in giuntion and detachment			Component deformation			Plaster or finiscing decay																								
					Total area: 2700 m ²			Ox1	Ox2	Ox3	Cr1	Cr2	Cr3	Gi1	Gi2	Gi3	Df1	Df2	Df3	De1	De2	De3																						
					Nº of Floors: 6																																							
Decision Support System		Survey output		Building Damage		Criticality		Cracks caused by rebar corrosion		Spalling		Heavy concrete spalling		Thin cracks		Medium cracks		Wide or active cracks		Defects at junction		Detachment of elements		Brick blocks falling down		Component deformation		Excessive deflection or deformations		Walls or elements leaning out of vertical		Decay phenomena (wet area, exfoliation)		Cracking of plaster or veneer		Detachment of plaster or veneer								
Tech. Unit		Element		Sub-element		CCr		Code		Component																																		
Code	Type	Code	Typology																																									
S	Str.	S2	Structural element	0.21	S2.2					Column																																		
				0.32	S2.3					Beam																																		
L	Load b.	L1	Slab	0.95	L1.4					Balcony or projection																																		
		L2	Connection	0.00	L2.1					Staircase																																		
				0.45	N1.1					Curtain wall																																		
		N1	Facade envelope	0.00	N1.2					Windows fixture																																		
				0.00	N2.1					External R.C. wall																																		
		N2	External wall	0.00	N2.2					External brick wall																																		
				0.00	N2.2					External brick wall																																		
		N4	Other	0.00	N4.1					Joint between elements																																		

F75	CITY		Puebla de Farnals		MATRIX OF DAMAGE		Cod	Ox			Cr			Gi			Df			De																								
	ADDRESS		Camino de la Playa		Registry data			R.C. Corrosion			Cracking pattern			Defect in giuntion and detachment			Component deformation			Plaster or finiscing decay																								
					Total area: 2700 m ²			Ox1	Ox2	Ox3	Cr1	Cr2	Cr3	Gi1	Gi2	Gi3	Df1	Df2	Df3	De1	De2	De3																						
					Nº of Floors: 6																																							
Decision Support System		Survey output		Building Damage		Criticality		Cracks caused by rebar corrosion		Spalling		Heavy concrete spalling		Thin cracks		Medium cracks		Wide or active cracks		Defects at junction		Detachment of elements		Brick blocks falling down		Component deformation		Excessive deflection or deformations		Walls or elements leaning out of vertical		Decay phenomena (wet area, exfoliation)		Cracking of plaster or veneer		Detachment of plaster or veneer								
Tech. Unit		Element		Sub-element		CCr		Code		Component																																		
Code	Type	Code	Typology																																									
S	Str.	S2	Structural element	0.00	S2.2					Column																																		
				0.00	S2.3					Beam																																		
L	Load b.	L1	Slab	1.42	L1.4					Balcony or projection																									15									
		L2	Connection	0.00	L2.1					Staircase																																		
				0.26	N1.1					Curtain wall																									16									
		N1	Facade envelope	0.00	N1.2					Windows fixture																																		
				0.00	N2.1					External R.C. wall																																		
		N2	External wall	0.00	N2.2					External brick wall																																		
				0.00	N2.2					External brick wall																																		
		N4	Other	0.00	N4.1					Joint between elements																																		

F58	CITY		Puebla de Farnals		MATRIX OF DAMAGE		Cod	Ox			Cr			Gi			Df			De		
	ADDRESS		Camino de la Playa		Registry data			R.C. Corrosion			Cracking pattern			Defect in giuntion and detachment			Component deformation			Plaster or finiscing decay		
					Total area: 2700 m ² N° of Floors: 6 Area of single floor: 450 m ² Construction typology: R.C. N° of buildings blocks: 3 Building Condition Rating: 1.15			Ox1			Cr1			Gi1			Df1			De1		
								Ox2			Cr2			Gi2			Df2			De2		
Desium Support System		Survey output							Cracks caused by rebar corrosion			Cracks caused by rebar corrosion			Cracks caused by rebar corrosion			Cracks caused by rebar corrosion			Cracks caused by rebar corrosion	
								Spalling			Heavy concrete spalling			Thin cracks			Medium cracks			Wide or active cracks		
								Cracks caused by rebar corrosion			Cracks caused by rebar corrosion			Cracks caused by rebar corrosion			Cracks caused by rebar corrosion			Cracks caused by rebar corrosion		
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								Cracks caused by rebar corrosion			Cracks caused by rebar corrosion			Cracks caused by rebar corrosion			Cracks caused by rebar corrosion			Cracks caused by rebar corrosion		
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								Cracks caused by rebar corrosion			Cracks caused by rebar corrosion			Cracks caused by rebar corrosion			Cracks caused by rebar corrosion			Cracks caused by rebar corrosion		
								Cracks caused by rebar corrosion			Cracks caused by rebar corrosion			Cracks caused by rebar corrosion			Cracks caused by rebar corrosion			Cracks caused by rebar corrosion		
								Cracks caused by rebar corrosion			Cracks caused by rebar corrosion			Cracks caused by rebar corrosion			Cracks caused by rebar corrosion			Cracks caused by rebar corrosion		
								Cracks caused by rebar corrosion			Cracks caused by rebar corrosion			Cracks caused by rebar corrosion			Cracks caused by rebar corrosion			Cracks caused by rebar corrosion		
								Cracks caused by rebar corrosion			Cracks caused											

F59	CITY		Puebla de Farnals		MATRIX OF DAMAGE		Cod	Ox			Cr			Gi			Df			De																	
	ADDRESS		Camino de la Playa		Registry data			R.C. Corrosion			Cracking pattern			Defect in giuntion and detachment			Component deformation			Plaster or finiscing decay																	
					Total area: 2700 m² N° of Floors: 6 Area of single floor: 450 m² Construction typology: R.C. N° of buildings blocks: 3 Building Condition Rating: 1.1			Ox1			Cr1			Gi1			Df1			De1																	
								Ox2			Cr2			Gi2			Df2			De2																	
Decision Support System		Survey output							Building Damages		Cracks caused by rebar corrosion		Cracks caused by rebar corrosion		Cracks caused by rebar corrosion		Cracks caused by rebar corrosion		Cracks caused by rebar corrosion		Cracks caused by rebar corrosion																
Tech. Unit		Element		Sub-element							Spalling		Heavy concrete spalling		Thin cracks		Medium cracks		Wide or active cracks		Defects at junction		Detachment of elements		Brick blocks falling down		Component deformation		Excessive deflection or deformations		Walls or elements leaning out of vertical		Decay phenomena (w et area, exfoliation)		Cracking of plaster or veneer		Detachment of plaster or veneer
Code		Type		Code		Typology		CCr		Code		Component																									
S		Str.		S2		Structural element		0.00		S2.2		Column																									
								0.00		S2.3		Beam																									
L		Load b.		L1		Slab		1.42		L1.4		Balcony or projection																									
				L2		Connection		0.00		L2.1		Staircase																									
N		Non load bearing		N1		Facade envelope		0.26		N1.1		Curtain wall																									
								0.00		N1.2		Windows fixture																									
				N2		External wall		0.00		N2.1		External R.C. wall																									
				N4		Other		0.00		N4.1		Joint between elements																									

F60	CITY		Puebla de Farnals		MATRIX OF DAMAGE		Cod	Ox			Cr			Gi			Df			De			
	ADDRESS		Camino de la Playa		Registry data			R.C. Corrosion			Cracking pattern			Defect in giuntion and detachment			Component deformation			Plaster or finiscing decay			
					Total area: 2700 m² Nº of Floors: 6 Area of single floor: 450 m² Construction typology: R.C. Nº of buildings blocks: 3 Building Condition Rating: 1.1			Ox1			Cr1			Gi1			Df1			De1			
								Ox2			Cr2			Gi2			Df2			De2			
Decision Support System	Survey output								Criticality	Cracks caused by rebar corrosion			Cracks caused by rebar corrosion			Cracks caused by rebar corrosion			Cracks caused by rebar corrosion			Cracks caused by rebar corrosion	
								Spalling			Heavy concrete spalling			Thin cracks			Medium cracks			Wide or active cracks			
Tech. Unit		Element		Sub-element				Spalling			Heavy concrete spalling			Thin cracks			Medium cracks			Wide or active cracks			
Code	Type	Code	Typology	CCr	Code	Component	Spalling			Heavy concrete spalling			Thin cracks			Medium cracks			Wide or active cracks				
S	Str.	S2	Structural element	0.00	S2.2	Column																	
				0.42	S2.3	Beam																	
L	Load b.	L1	Slab	0.51	L1.4	Balcony or projection														6			
				0.00	L2.1	Staircase																8	
N	Non load bearing	N1	Facade envelope	0.43	N1.1	Curtain wall														5			
				0.00	N1.2	Windows fixture																	
				0.00	N2.1	External R.C. wall																	
				0.00	N2.2	External brick wall																	
		N4	Other	0.00	N4.1	Joint between elements																	

F01		CITY		Puebla de Farnals		MATRIX OF DAMAGE			Cod	Ox			Cr			Gi			Df			De		
		ADDRESS		Camino de la Playa		Registry data				R.C. Corrosion			Cracking pattern			Defect in giuntion and detachment			Component deformation			Plaster or finiscing decay		
Decision Support System		Survey output				Total area: 2700 m ²				Cracks caused by rebar corrosion			Thin cracks			Defects at junction			Component deformation			Decay phenomena (wet area, exfoliation)		
						N° of Floors: 6			Spalling			Medium cracks			Detachment of elements			Excessive deflection or deformations			Cracking of plaster or veneer			
						Area of single floor: 450 m ²			Heavy concrete spalling			Wide or active cracks			Brick blocks falling down			Walls or elements leaning out of vertical			Detachment of plaster or veneer			
						Construction typology: R.C.																		
						N° of buildings blocks: 3																		
				Building Condition Rating:																				
				1.13																				
Tech. Unit		Element		Sub-element			Criticality			Cracks caused by rebar corrosion			Thin cracks			Defects at junction			Component deformation			Decay phenomena (wet area, exfoliation)		
Code	Type	Code	Typology	CCr	Code	Component				Spalling			Medium cracks			Detachment of elements			Excessive deflection or deformations			Cracking of plaster or veneer		
S	Str.	S2	Structural element	0.00	S2.2	Column																		
				0.00	S2.3	Beam																		
L	Load b.	L1	Slab	0.62	L1.4	Balcony or projection																9		
		L2	Connection	0.00	L2.1	Staircase																		
N	Non load bearing	N1	Facade envelope	0.22	N1.1	Curtain wall																8		
				0.00	N1.2	Windows fixture																		
		N2	External wall	0.00	N2.1	External R.C. wall																		
				0.00	N2.2	External brick wall																		
		N4	Other	0.00	N4.1	Joint between elements																		

F02	CITY		Puebla de Farnals		MATRIX OF DAMAGE		Cod	Ox			Cr			Gi			Df			De																	
	ADDRESS		Camino de la Playa		Registry data			R.C. Corrosion			Cracking pattern			Defect in giuntion and detachment			Component deformation			Plaster or finiscing decay																	
			Total area: m²		Nº of Floors:			Area of single floor: m²		Construction typology: R.C.		Nº of buildings blocks:		Building Condition Rating:		7.66																					
Decision Support System			Survey output		Building Damage		Criticality		Cracks caused by rebar corrosion		Spalling		Heavy concrete spalling		Thin cracks		Medium cracks		Wide or active cracks		Defects at junction		Detachment of elements		Brick blocks falling down		Component deformation		Excessive deflection or deformations		Walls or elements leaning out of vertical		Decay phenomena (wet area, exfoliation)		Cracking of plaster or veneer		Detachment of plaster or veneer
Tech. Unit		Element				Sub-element				Cracks caused by rebar corrosion		Thin cracks		Defects at junction		Component deformation		Excessive deflection or deformations		Walls or elements leaning out of vertical		Decay phenomena (wet area, exfoliation)		Cracking of plaster or veneer		Detachment of plaster or veneer											
Code	Type	Code	Typology	CCr	Code	Component	Criticality		Spalling		Heavy concrete spalling		Thin cracks		Medium cracks		Wide or active cracks		Defects at junction		Detachment of elements		Brick blocks falling down		Component deformation		Excessive deflection or deformations		Walls or elements leaning out of vertical		Decay phenomena (wet area, exfoliation)		Cracking of plaster or veneer		Detachment of plaster or veneer		
S	Str.	S2	Structural element	0.18	S2.2	Column	12		16																				10		10						
L	Load b.	L1	Slab	3.80	L1.4	Balcony or projection	18		34																				42								
		L2	Connection	0.00	L2.1	Staircase																															
N	Non load bearing	N1	Facade envelope	2.68	N1.1	Curtain wall																							135		45						
		N2	External wall	0.00	N1.2	Windows fixture																															
				0.00	N2.1	External R.C. wall																															
				0.00	N2.2	External brick wall																															
		N4	Other	0.10	N4.1	Joint between elements							2																								

Playa Puig

PP1	CITY		Playa Puig		MATRIX OF DAMAGE			Cod	Ox			Cr			Gi			Df			De		
	ADDRESS		Urbanización Playa Puig		Registry data				R.C. Corrosion			Cracking pattern			Defect in giuntion and detachment			Component deformation			Plaster or finiscing decay		
			Total area: 10080 m²			Nº of Floors: 21			Area of single floor: 480 m²			Construction typology: R.C.			Nº of buildings blocks: 1			Building Condition Rating:					
Decision Support System		Survey output		Building Damage			Cod	Cracks caused by rebar corrosion			Cracks caused by rebar corrosion			Cracks caused by rebar corrosion			Cracks caused by rebar corrosion			Cracks caused by rebar corrosion			
Tech. Unit		Element			Sub-element			Criticality	Cracks caused by rebar corrosion			Cracks caused by rebar corrosion			Cracks caused by rebar corrosion			Cracks caused by rebar corrosion			Cracks caused by rebar corrosion		
Code	Type	Code	Typology	CCr	Code	Component		Ox1	Ox2	Ox3	Cr1	Cr2	Cr3	Gi1	Gi2	Gi3	Df1	Df2	Df3	De1	De2	De3	
S	Str.	S2	Structural element	0.42	S2.2	Column	8														50		
				0.16	S2.3	Beam																	
L	Load b.	L1	Slab	2.75	L1.4	Balcony or projection															160		
		L2	Connection	0.00	L2.1	Staircase																	
N	Non load bearing	N1	Facade envelope	0.18	N1.1	Curtain wall															21		
				0.00	N1.2	Windows fixture																	
		N2	External wall	0.00	N2.1	External R.C. wall																	
				0.00	N2.2	External brick wall																	
		N4	Other	0.00	N4.1	Joint between elements																	

PP2	CITY		Playa Puig		MATRIX OF DAMAGE		Cod	Ox			Cr			Gi			Df			De		
	ADDRESS		Les marines 1		Registry data			R.C. Corrosion			Cracking pattern			Defect in giuntion and detachment			Component deformation			Plaster or finiscing decay		
Decision Support System Survey output					Total area: 9240 m²		Building Damage Criticality Cracks caused by rebar corrosion Spalling Heavy concrete spalling Thin cracks Medium cracks Wide or active cracks Defects at junction Detachment of elements Brick blocks falling down Component deformation Excessive deflection or deformations Walls or elements leaning out of vertical Decay phenomenon (wet area, exfoliation) Cracking of plaster or veneer Detachment of plaster or veneer	Ox1	Ox2	Ox3	Cr1	Cr2	Cr3	Gi1	Gi2	Gi3	Df1	Df2	Df3	De1	De2	De3
					Nº of Floors: 21																	
					Area of single floor: 440 m²																	
					Construction typology: R.C.																	
					Nº of buildings blocks: 1																	
					Building Condition Rating: 2.11																	
Tech. Unit		Element		Sub-element		Cracks caused by rebar corrosion		Cracking pattern		Defect in giuntion and detachment		Component deformation		Plaster or finiscing decay								
Code	Type	Code	Typology	CCr	Code	Component	Ox1	Ox2	Ox3	Cr1	Cr2	Cr3	Gi1	Gi2	Gi3	Df1	Df2	Df3	De1	De2	De3	
S	Str.	S2	Structural element	0.18	S2.2	Column Beam															20	
				0.00	S2.3																	
L	Load b.	L1	Slab	3.10	L1.4	Balcony or projection Staircase														80	18	
				0.00	L2.1																	
N	Non load bearing	N1	Facade envelope	0.19	N1.1	Curtain wall Windows fixture															21	
				0.00	N1.2																	
		N2	External wall	0.00	N2.1	External R.C. wall External brick wall																
				0.00	N2.2																	
			N4	Other	0.00	N4.1	Joint between elements															

PP3		CITY		Playa Puig		MATRIX OF DAMAGE		Cod	Ox			Cr			Gi			Df			De			
		ADDRESS		Camino Playa		Registry data			R.C. Corrosion			Cracking pattern			Defect in giuntion and detachment			Component deformation			Plaster or finiscing decay			
Decision Support System Survey output						Total area: 12000 m²		Building Damage Criticality	Ox1			Cr1			Gi1			Df1			De1			
						Nº of Floors: 15			Ox2			Cr2			Gi2			Df2			De2			
						Area of single floor: 800 m²			Ox3			Cr3			Gi3			Df3			De3			
						Construction typology: R.C.			Cracks caused by rebar corrosion			Medium cracks			Defects at junction			Excessive deflection or deformations			Decay phenomenon (wet area, exfoliation)			
						Nº of buildings blocks: 2			Spalling			Wide or active cracks			Detachment of elements			Walls or elements leaning out of vertical			Cracking of plaster or veneer			
						Building Condition Rating:			Heavy concrete spalling						Brick blocks falling down			Component deformation			Detachment of plaster or veneer			
				1.6																				
Tech. Unit		Element				Sub-element				Cracks caused by rebar corrosion			Cracking pattern			Defect in giuntion and detachment			Component deformation			Plaster or finiscing decay		
Code	Type	Code	Typology		CCr	Code	Component		Ox1	Ox2	Ox3	Cr1	Cr2	Cr3	Gi1	Gi2	Gi3	Df1	Df2	Df3	De1	De2	De3	
S	Str.	S2	Structural element		0.13	S2.2	Column														8	4		
					0.00	S2.3	Beam																	
L	Load b.	L1	Slab		2.38	L1.4	Balcony or projection														43	23		
		L2	Connection		0.00	L2.1	Staircase																	
N	Non load bearing	N1	Facade envelope		0.15	N1.1	Curtain wall														15	3		
					0.00	N1.2	Windows fixture																	
		N2	External wall		0.00	N2.1	External R.C. wall																	
					0.00	N2.2	External brick wall																	
			N4	Other		0.00	N4.1	Joint between elements																

PP4	CITY		Playa Puig		MATRIX OF DAMAGE		Cod	Ox			Cr			Gi			Df			De																				
	ADDRESS		Calle Semillar		Registry data			Macro Type	R.C. Corrosion			Cracking pattern			Defect in giuntion and detachment			Component deformation			Plaster or finising decay																			
					Total area: 9702 m²				Cod	Ox1	Ox2	Ox3	Cr1	Cr2	Cr3	Gi1	Gi2	Gi3	Df1	Df2	Df3	De1	De2	De3																
					Nº of Floors: 3					Cracks caused by rebar corrosion			Spalling			Heavy concrete spalling			Thin cracks			Medium cracks																		
Decision Support System		Survey output				Area of single floor: 3234 m²		Building Damage			Wide or active cracks			Defects at junction			Detachment of demants			Brick blocks falling down			Component deformation			Excessive deflection or deformations			Walls or elements leaning out of vertical			Decay phenomena (wet area, exfoliation)			Cracking of plaster or veneer			Detachment of plaster or veneer		
Tech. Unit		Element		Sub-element		Building Condition Rating:																																		
Code	Type	Code	Typology	CCr	Code	Component																																		
S	Str.	S2	Structural element	0.04	S2.2	Column	4																																	
				0.00	S2.3	Beam																																		
L	Load b.	L1	Slab	0.08	L1.4	Balcony or projection																									4									
		L2	Connection	0.00	L2.1	Staircase																																		
N	Non load bearing	N1	Facade envelope	0.04	N1.1	Curtain wall							2																		4									
				0.00	N1.2	Windows fixture																																		
		N2	External wall	0.00	N2.1	External R.C. wall																																		
				0.00	N2.2	External brick wall																																		
		N4	Other	0.00	N4.1	Joint between elements																																		

PP5	CITY		Playa Puig		MATRIX OF DAMAGE		Macro Type	Ox			Cr			Gi			Co			De			
	ADDRESS		Calle Semillar		Registry data			R.C. Corrosion			Cracking pattern			Defect in giuntion and detachment			Corrosion			Plaster or finising decay			
					Total area: 3246 m²			Cracks caused by rebar corrosion	Ox1	Ox2	Ox3	Cr1	Cr2	Cr3	Gi1	Gi2	Gi3	Cs1	Cs2	Cs3	De1	De2	De3
					Nº of Floors: 6																		
Decision Support System Survey output					Area of single floor: 541 m²		Building Damage	Criticality	Spalling	Heavy concrete spalling	Thin cracks	Medium cracks	Wide or active cracks	Defects at junction	Detachment of elements	Brick blocks falling down	Corrosion of steel element	Yielding	Corrosion with section reduction	Decay phenomena (wet area, exfoliation)	Cracking of plaster or veneer	Detachment of plaster or veneer	
					Construction typology: R.C.																		
					Nº of buildings blocks: 1																		
				Building Condition Rating:																			
				3.2																			
Tech. Unit		Element		Sub-element																			
Code	Type	Code	Typology	CCr	Code	Component																	
S	Str.	S2	Structural element	0.00	S2.2	Column																	
				0.48	S2.3	Beam	10																
L	Load b.	L1	Slab	3.31	L1.4	Balcony or projection													25				
		L2	Connection	0.00	L2.1	Staircase													10				
N	Non load bearing	N1	Facade envelope	0.28	N1.1	Curtain wall													20				
				0.41	N1.2	Windows fixture																	
		N2	External wall	0.00	N2.1	External R.C. wall											10						
				0.00	N2.2	External brick wall																	
		N4	Other	0.00	N4.1	Joint between elements																	

PP6	CITY		Playa Puig		MATRIX OF DAMAGE		Macro Type	Ox			Cr			Gi			Df			De		
	ADDRESS		Calle Semillar		Registry data			R.C. Corrosion			Cracking pattern			Defect in giuntion and detachment			Component deformation			Plaster or finiscing decay		
					Total area: 3600 m ²			Ox1	Ox2	Ox3	Cr1	Cr2	Cr3	Gi1	Gi2	Gi3	Df1	Df2	Df3	De1	De2	De3
					Nº of Floors: 8			Building Damage	Cracks caused by rebar corrosion			Spalling			Heavy concrete spalling			Thin cracks			Medium cracks	
Tech. Unit		Element		Sub-element		Wide or active cracks			Defects at junction			Detachment of elements			Brick blocks falling down			Component deformation				
Code	Type	Code	Typology	CCr	Code	Component	Excessive deflection or deformations			Walls or elements leaning out of vertical			Decay phenomena (wet area, exfoliation)			Cracking of plaster or veneer						
S	Str.	S2	Structural element	0.00	S2.2	Column																
				0.00	S2.3	Beam																
L	Load b.	L1	Slab	1.-6	L1.4	Balcony or projection													15			
		L2	Connection	0.00	L2.1	Staircase																
N	Non load bearing	N1	Facade envelope	0.19	N1.1	Curtain wall													16			
				0.00	N1.2	Windows fixture																
		N2	External wall	0.00	N2.1	External R.C. wall																
				0.00	N2.2	External brick wall																
		N4	Other	0.00	N4.1	Joint between elements																

[illegible]

TPS	CITY		Playa Puig		MATRIX OF DAMAGE		Cod Macro Type	Ox			Cr			Gi			Df			De			
	ADDRESS		Calle Semillar		Registry data			R.C. Corrosion			Cracking pattern			Defect in giuntion and detachment			Component deformation			Plaster or finishing decay			
Decision Support System Survey output					Total area: 7740 m ²		Building Damage	Cracks caused by rebar corrosion	Ox1	Ox2	Ox3	Cr1	Cr2	Cr3	Gi1	Gi2	Gi3	Df1	Df2	Df3	De1	De2	De3
					N° of Floors: 9																		
					Area of single floor: 860 m ²																		
					Construction typology: R.C.																		
					N° of buildings blocks: 3																		
					Building Condition Rating:																		
		0.52																					
Tech. Unit		Element			Sub-element																		
Code	Type	Code	Typology	CcR	Code	Component																	
S	Str.	S2	Structural element	0.00 0.06	S2.2 S2.3	Column Beam	3																
L	Load b.	L1	Slab	0.50	L1.4	Balcony or projection																	
		L2	Connection	0.00	L2.1	Staircase																	
N	Non load bearing	N1	Facade envelope	0.12 0.00	N1.1 N1.2	Curtain wall Windows fixture																	
		N2	External wall	0.00	N2.1	External R.C. wall																	
		N4	Other	0.00	N2.2	External brick wall																	
						Joint between elements																	

[illegible]

PP10		CITY		Playa Puig		MATRIX OF DAMAGE		Cod. Type	Ox			Cr			Gi			Df			De																																
		ADDRESS		Calle Semillar		Registry data			R.C. Corrosion			Cracking pattern			Defect in giunion and detachment			Component deformation			Plaster or finishing decay																																
Decision Support System	Survey output			Total area: 4500 m²		Nº of Floors: 15			Area of single floor: 300 m²		Construction typology: R.C.		Nº of buildings blocks: 1		Building Condition Rating:																																						
				1.62																																																	
								Building Damage	Cracks caused by rebar corrosion			Spalling			Heavy concrete-spalling			Thin cracks			Medium cracks			Wide or active cracks			Defects at junction			Detachment of elements			Brick blocks falling down			Component deformation			Excessive deflection or deformations			Walls or elements leaning out of vertical			Decay phenomena (wet area, exfoliation)			Cracking of plaster or veneer			Detachment of plaster or veneer		
									Ox1			Ox2			Ox3			Cr1			Cr2			Cr3			Gi1			Gi2			Gi3			Df1			Df2			Df3			De1			De2			De3		
									Criticality																																												
Tech. Unit		Element				Sub-element																																															
Code		Type		Code		Typology		CCr		Code		Component																																									
S		Str		S2		Structural element		0.00		S2.2		Column																																									
								0.00		S2.3		Beam																																									
L		Load b.		L1		Slab		0.00		L1.4		Balcony or projection																																									
				L2		Connection		0.00		L2.1		Staircase																																									
N		Non load bearing		N1		Facade envelope		0.00		N1.1		Curtain wall																																									
								0.00		N1.2		Windows fixture																																									
				N2		External wall		0.00		N2.1		External R.C. wall																																									
								0.00		N2.2		External brick wall																																									
				Other				0.00		N4.1		Joint between elements																																									

PP11	CITY		Playa Puig		MATRIX OF DAMAGE		Cod. Type	Ox			Cr			Gi			Df			De																																																																											
	ADDRESS		Calle la Palma		Registry data			R.C. Corrosion			Cracking pattern			Defect in giunion and detachment			Component deformation			Plaster or finishing decay																																																																											
					Total area: 9600 m ² Nº of Floors: 15 Area of single floor: 1600 m ² Construction typology: R.C. Nº of buildings blocks: 3 Building Condition Rating: 0.96			Ox1			Cr1			Gi1			Df1			De1																																																																											
								Ox2			Cr2			Gi2			Df2			De2																																																																											
Decision Support System Survey output							Building Damage	Cracks caused by rebar corrosion			Spalling			Heavy concrete spalling			Thin cracks			Medium cracks			Wide or active cracks			Defects at junction			Detachment of elements			Brick blocks falling down			Component deformation			Excessive deflection or deformations			Walls or elements leaning out of vertical			Decay phenomena (wet area, exfoliation)			Cracking of plaster or veneer			Detachment of plaster or veneer																																													
Tech. Unit								S			L			N			Non load bearing			Load b.			Str.			S2			Structural element			CCr			Code			Component			S2.2			Column			S2.3			Beam			L1.4			Balcony or projection			L2.1			Staircase			N1.1			Curtain wall			N1.2			Windows fixture			N2.1			External R.C. wall			N2.2			External brick wall			N4.1			Joint between elements			
Code								Type			Code			Typology			CCr			Code			Component			S2.2			Column			S2.3			Beam			L1.4			Balcony or projection			L2.1			Staircase			N1.1			Curtain wall			N1.2			Windows fixture			N2.1			External R.C. wall			N2.2			External brick wall			N4.1			Joint between elements																		
Code								Type			Code			Typology			CCr			Code			Component			S2.2			Column			S2.3			Beam			L1.4			Balcony or projection			L2.1			Staircase			N1.1			Curtain wall			N1.2			Windows fixture			N2.1			External R.C. wall			N2.2			External brick wall			N4.1			Joint between elements																		

Decision Support System	Survey output	CITY		Playa Puig		MATRIX OF DAMAGE		Cod. Type	Ox			Cr			Gi			Df			De			
		ADDRESS		Calle de Lanzarote		Registry data			R.C. Corrosion			Cracking pattern			Defect in giunion and detachment			Component deformation			Plaster or finishing decay			
						Total area: 9600 m² Nº of Floors: 15 Area of single floor: 1600 m² Construction typology: R.C. Nº of buildings blocks: 3 Building Condition Rating: 0.8			Ox1			Cr1			Gi1			Df1			De1			
									Ox2			Cr2			Gi2			Df2						
		Tech. Unit		Element		Sub-element		Cracks caused by rebar corrosion			Cracks caused by rebar corrosion			Cracks caused by rebar corrosion			Cracks caused by rebar corrosion			Cracks caused by rebar corrosion				
		Code		Type		Code		Component		Spalling			Medium cracks			Detachment of elements			Excessive deflection or deformations			Detachment of plaster or veneer		
S	Str.	S2	Structural element	0.00	S2.2		Column																	
				0.06	S2.3		Beam																	
L	Load b.	L1	Slab	1.18	L1.4		Balcony or projection													9	1			
				0.00	L2.1		Staircase																	
N	Non load bearing	N1	Facade envelope	0.08	N1.1		Curtain wall																	
				0.00	N1.2		Windows fixture																	
		N2	External wall	0.00	N2.1		External R.C. wall																	
				0.00	N2.2		External brick wall																	
		N4	Other	0.00	N4.1		Joint between elements																	

PP13	CITY		Playa Puig		MATRIX OF DAMAGE		Cod	Ox			Cr			Gi			Df			De				
	ADDRESS		Calle Fuerteventura		Registry data			R.C. Corrosion			Cracking pattern			Defect in giuntion and detachment			Component deformation			Plaster or finisning decay				
					Total area: 9600 m ²			Ox1			Cr1			Gi1			Df1			De1				
					Nº of Floors: 15			Ox2		Cr2			Gi2			Df2			De2					
Decision Support System	Survey output				Area of single floor: 1600 m ²		Building Damage	Ox3			Cr3			Gi3			Df3			De3				
					Construction typology: R.C.			Cracks caused by rebar corrosion			Spalling			Defects at junction			Component deformation			Decay phenomena (wet area, exfoliation)				
					Nº of buildings blocks: 3			Spalling			Heavy concrete spalling			Detachment of elements			Excessive deflection or deformations			Cracking of plaster or veneer				
					Building Condition Rating:									Brick blocks falling down			Walls or elements leaning out of vertical			Detachment of plaster or veneer				
Tech. Unit		Element		Sub-element																				
Code	Type	Code	Typology	CCr	Code	Component																		
S	Str.	S2	Structural element	0.00	S2.2	Column																		
				0.05	S2.3	Beam											8							
L	Load b.	L1	Slab	1.03	L1.4	Balcony or projection														60				
		L2	Connection	0.00	L2.1	Staircase																		
N	Non load bearing	N1	Facade envelope	0.07	N1.1	Curtain wall														16				
				0.00	N1.2	Windows fixture																		
		N2	External wall	0.00	N2.1	External R.C. wall																		
				0.00	N2.2	External brick wall																		
		N4	Other	0.00	N4.1	Joint between elements																		

PP14	CITY		Playa Puig		MATRIX OF DAMAGE		Cod	Ox			Cr			Gi			Df			De																																
	ADDRESS		Av. Tramontana		Registry data			R.C. Corrosion			Cracking pattern			Defect in giuntion and detachment			Component deformation			Plaster or finishing decay																																
					Total area: 1200 m ²			Ox1			Cr1			Gi1			Df1			De1																																
					Nº of Floors: 8			Ox2		Cr2			Gi2			Df2			De2																																	
Decision Support System	Survey output				Area of single floor: 1500 m ²		Building Damage	Cracks caused by rebar corrosion			Spalling			Heavy concrete spalling			Thin cracks			Medium cracks			Wide or active cracks			Defects at junction			Detachment of elements			Brick blocks falling down			Component deformation			Excessive deflection or deformations			Walls or elements leaning out of vertical			Decay phenomena (wet area, exfoliation)			Cracking of plaster or veneer			Detachment of plaster or veneer		
					Construction typology: R.C.			Ox3			Cr3			Gi3			Df3			De3																																
					Nº of buildings blocks: 8																																															
					Building Condition Rating: 1.63																																															
Tech. Unit		Element		Sub-element																																																
Code	Type	Code	Typology	CCr	Code	Component																																														
S	Str.	S2	Structural element	0.26	S2.2	Column																															32															
				0.40	S2.3	Beam					30		6																								30															
L	Load b.	L1	Slab	0.50	L1.4	Balcony or projection																															29															
		L2	Connection	0.00	L2.1	Staircase																																														
N	Non load bearing	N1	Facade envelope	0.25	N1.1	Curtain wall																													32		16															
				0.00	N1.2	Windows fixture																																														
		N2	External wall	0.00	N2.1	External R.C. wall																																														
				0.00	N2.2	External brick wall																																														
		N4	Other	0.00	N4.1	Joint between elements																																														

PP15	CITY		Playa Puig		MATRIX OF DAMAGE		Cod	Ox			Cr			Gi			Df			De																	
	ADDRESS		Av. Tramontana		Registry data			R.C. Corrosion			Cracking pattern			Defect in giuntion and detachment			Component deformation			Plaster or finishing decay																	
					Total area: 11730 m ²			Ox1			Cr1			Gi1			Df1			De1																	
					Nº of Floors: 17			Ox2		Cr2			Gi2			Df2			De2																		
Decision Support System	Survey output				Area of single floor: 690 m ²		Building Damage	Ox3			Cr3			Gi3			Df3			De3																	
					Construction typology: R.C.			Cracks caused by rebar corrosion			Spalling			Heavy concrete spalling			Defects at junction			Component deformation			Excessive deflection or deformations			Walls or elements leaning out of vertical			Decay phenomena (wet area, exfoliation)			Cracking of plaster or veneer			Detachment of plaster or veneer		
					Nº of buildings blocks: 1																																
					Building Condition Rating:																																
				0.21																																	
Tech. Unit		Element		Sub-element																																	
Code	Type	Code	Typology	CCr	Code	Component																															
S	Str.	S2	Structural element	0.14	S2.2	Column																															
				0.00	S2.3	Beam																															
L	Load b.	L1	Slab	0.75	L1.4	Balcony or projection																															
				0.00	L2.1	Staircase																															
N	Non load bearing	N1	Facade envelope	0.30	N1.1	Curtain wall																															
				0.00	N1.2	Windows fixture																															
				0.00	N2.1	External R.C. wall																															
				0.00	N2.2	External brick wall																															
				0.00	N4	Other																															
				0.00		Joint between elements																															

PP16	CITY		Playa Puig		MATRIX OF DAMAGE		Cod. Macro Type	Ox			Cr			Gi			Df			De							
	ADDRESS		Av. Tramontana		Registry data			R.C. Corrosion			Cracking pattern			Defect in giuntion and detachment			Component deformation			Plaster or finishing decay							
			Total area: 11730 m²		Nº of Floors: 17			Ox1	Ox2	Ox3	Cr1	Cr2	Cr3	Gi1	Gi2	Gi3	Df1	Df2	Df3	De1	De2	De3					
			Area of single floor: 690 m²		Construction typology: R.C.			Cracks caused by rebar corrosion	Spalling	Heavy concrete spalling	Thin cracks	Medium cracks	Wide or active cracks	Defects at junction	Detachment of elements	Brick blocks falling down	Component deformation	Excessive deflection or deformations	Walls or elements leaning out of vertical	Decay phenomena (wet area, exfoliation)	Cracking of plaster or veneer	Detachment of plaster or veneer					
			Nº of buildings blocks: 1		Building Condition Rating:																						
			1.33																								
Tech. Unit		Element		Sub-element		Building Damage		Cracks caused by rebar corrosion			Cracking pattern			Defect in giuntion and detachment			Component deformation			Plaster or finishing decay							
Code	Type	Code	Typology	CCr	Code	Component	Cracks caused by rebar corrosion			Cracking pattern			Defect in giuntion and detachment			Component deformation			Plaster or finishing decay								
S	Str.	S2	Structural element	0.17	S2.2	Column						6							14								
				0.30	S2.3	Beam														30	30						
L	Load b.	L1	Slab	0.48	L1.4	Balcony or projection													29								
				0.00	L2.1	Staircase																					
N	Non load bearing	N1	Facade envelope	0.25	N1.1	Curtain wall													32		16						
				0.00	N1.2	Windows fixture																					
			N2	External wall	0.00	N2.1	External R.C. wall																				
					0.00	N2.2	External brick wall																				
		N4	Other	0.00	N4.1	Joint between elements																					