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1 Introduction

The difficult beginning of XXI century has openly confirmed a worldwide concern about increasingly differentiated social, economic, environmental issues, as well as a need of more focused commitment on spatial planning and environmental management in local communities. Dealing with urban renewal challenges involves the coordination of multiple stakeholders in overcomplicated planning processes (Soma et al., 2017). However, knowledge issues connected with such need have to face the widespread awareness of an intriguing, yet interlaced complexity of the environmental domain. In this framework, researches dealing with environmental complexity and knowledge have continuously increased in recent times (Maturana & Varela, 1987; Newman & Jennings, 2008; Prigogine & Stengers, 1984). Beyond the ethical prerogative of enhancing the environment *per se*, interest is also addressed to environmental resources, as a potential of wealth and development for communities (Maciocco, 2008).

Due to environmental complexity, as well as to the multifarious, formal and informal languages used by agents, knowledge poses a number of concerns about its elicitation, formalization and organization. In multi-actors settings, the deep understanding of similarities, differences, ambiguities between different sources of knowledge is pivotal in the field of knowledge management and integration in successful participatory processes (e.g. Brugnach et al., 2008, Brugnach and Ingram, 2012; Giordano et al., 2017; Santoro et al., 2019).

Under this perspective, urban plans are now increasingly considered as knowledge-building processes, largely signified and *value-added* by community cognitive agents and social, economic, environmental stakeholders (Khakee et al., 2000). Understanding stakeholders' roles, goals, problem formulations, expectations has become a crucial subject of analysis and research (e.g. Bryson, 2004; Herazo et al., 2016; Ferretti et al., 2018). In this context, the main research problem addressed by the present work is to explore possible socio-economic and environmental knowledge management approaches, oriented to support public planning decisions in complex urban environments. The research investigation will be carried out in a real-world arena, starting from problematic areas of urban industrial decay.

The research is rooted in the framework of *Futures Studies*, using a *scenario-building* (SB) orientation in development plans (Khakee et al., 2002a). Yet recently, part of the methodological focus has been slightly improved by cognitive-mapping-based tools, particularly on cross impact evaluations. Specifically, fuzzy cognitive mapping (FCM) has been developed, and a fair number of applications have been realized raising interest and significant implementation in environmental domain (e.g. Jetter et al.,, 2014; Damart, 2010; Elsawah ET AL., 2015; Giordano et al. 2017a).

The current work is carried out in the SB activity developed within the process for the drawing out of the new master plan of Taranto (Italy) – a difficult context with decaying industrial economy and environment degradation (Camarda et al., 2014). In this context, we investigate the potentials of the FCM approach in a process of knowledge sharing and enrichment for urban planning purposes. The use of FCM was not included in the original plan layout and was decided as an attempt to overcome a political *impasse* in the process. Despite such 'accidental' initial condition, interesting explorations and suggestions on some potentials of this approach in a real-life operational context are shown. Limitations emerge too, connected with the mostly qualitative level of reflections allowed by the above condition. In this context, a thorough evaluation and confrontation of FCM with other methodologies becomes far from the range of the present study and therefore will not be carried out.

Within the above framework, the paper is structured as follows. After the present introduction, chapter 2 deals with the foundation and methodology of fuzzy-based approach in scenario analysis, whereas chapter 3 and 4 describe and discuss the Taranto case study with FCM application. Some final notes end up the work.

2 Fuzzy cognitive mapping in scenario analysis: research issues

2.1 Motivation and research questions

Knowledge is a critical factor in setting up planning processes. According to Rittel and Webber (1973) its management belongs to the so-called category of "wicked" problems in planning, oriented to problem structuring more than solving, in a decisionmaking political context. Generally, knowledge is considered as a multiform, multi-agent, dynamic disposition, being complex as it mirrors the phenomenological-relational complexity of the environment it refers to (Maturana, Varela, 1987, pp.47, 65). From an agent-based point of view, increasingly shared today, knowledge contents are characterized by different types of agents. There are agents with technical, scientific, domain knowledge, or even applied knowledge, expressed through structured and formalized languages (expert agents). On the other hand, there are agents with essentially experiential, empirical knowledge, derived from common sense and typically unstructured and informal ('non-expert' agents). The cognitive and informative dignity of both agent types is now recognized as being substantially comparable (Fischer, 2000; Friedmann, 1987; Schön, 1983). In particular, in spatial planning processes, the cognitive role of non-expert agents needs to integrate significantly the more traditional role of experts, for reasons of knowledge and implementation effectiveness of the process (Khakee et al., 2000).

Our main research problem is how to manage socio-economic and environmental knowledge, oriented to support public planning decisions in complex urban environments, starting from problematic areas including urban peripheries.

However, particularly non-expert knowledge is often informal, puzzling, uncertain, incomplete, and hard to be formalized and modelled. In this sense, cognitive models are useful to deal with the unmanageability typically embedded in highly complex domains and to enhance knowledge management (e.g. Eden 1988, Sawyer, 2005, Ackermann et al., 2016). These models are basis for the building up of multi-agent system (MAS) architectures to support decisionmaking in land use and policymaking planning (e.g. Wierzbicki, Makowski, & Wessels, 2000; Borri et al., 2008; Eden et al. 2013). A MAS-based knowledge analysis is able to enhance the handling of qualitative and quantitative data, formal as well as informal contents, through opportune modelling approaches for *future scenarios* (Khakee et al., 2002b; Borri et al.; 2004; Borri & Camarda, 2006, 2011). Future-scenario process stems from a variant of the *strategic choice* approach (Friend and Hickling, 1997), further modified by *futures studies*, particularly by the known *future workshop* methodology by Jungk and Mullert (1996). The variant is basically made up of a sequence of interactive meetings, in which participants carry out brainstorming iterations to identify strategic courses to build alternative development scenarios. A synthetic account of this part of the process is shown in table 1.

Future Workshop		
Phase	**Contents**	**Expected Results**
Preparation	The issue to be analysed is decided and the structure and environment of sessions are prepared	Summary of contributions

Critique	Dissatisfactions and negative experiences of the present situation are expressed and discussed	Definition of problematic areas for subsequent discussions
Fantasy	As an answer to problems, free generation of ideas and of desires, dreams, fantasies, opinions concerning the future. Participants are asked to forget practical limitation and obstacles of the present reality	Indication of a collection of ideas; selection of some solutions and planning guidelines
Implementation	Participants go back to the present reality, to its power structures and to its real limits to analyse the actual feasibility of the previous solutions and ideas. They identify obstacles and limits to the plan implementation, as well as possible ways to overcome them	Creation of strategic lines to be followed in order to fulfil the traced goals. Drawing of action plan and implementation proposal

Table 1. *The future workshop* methodology (Khakee et al., 2002a, p.586).

Scenarios analysis suggests that the elements characterizing socio-environmental systems are not isolated. Rather, they look fairly interconnected through a dense and complex web of feedbacks. Recently, the methodological focus has been slightly improved by FCM-based tools, particularly on cross impact evaluations. Specifically, FCM has been used and a fair number of applications have been implemented with significance (Giordano et al., 2013; Ozesmi & Ozesmi, 2004). For instance, FCM-based tools, integrated with other approaches (e.g. system dynamics, social network analysis), are crucial to support decision makers in improving the resilience of urban areas (Pagano et al., 2017), sustainable resources management (Pluchinotta et al., 2018) and the understanding of interaction network during natural emergencies (Giordano et al., 2017a). FCM is a technique for modelling complex real-world situations, aiming at integrating knowledge from multiple actors, disciplines and sectors, including the public sector (Kosko, 1986, Kosko, 1988, Stach et al., 2010). Models based on FCM allow the use of local stakeholders' knowledge for environmental modelling in participatory and interactive management schemes. As found out experimentally, FCMs can also qualitatively support stakeholders' representation of environmental problems, through a multi-agent approach (Borri et al., 2013, 2014).

Following this knowledge-oriented approach, the current research is carried out in the scenario-building (SB) activity developed within the process for the drawing out of the new master plan of Taranto (Italy). A number of focus group (FG) sessions, conducted among the community stakeholders, represents the basis for FCM analysis.

In this work, we investigate on the potentials of the used approach in a process of knowledge sharing and enrichment for urban planning purposes. Particularly, a major motivation is to investigate a FCM-based approach used to enhance local common knowledge in a planning process, particularly in situations of time constraints that do not allow extensive scenario-building processes. A specific objective of the research is to understand the extent to which a fuzzy-based (i.e., a logic-based) model (Zadeh, 1973) can integrate a scenario-oriented process based on the statistical analysis of unstructured, informal, incomplete knowledge.

It is important to remark that the use of FCM was not included in the original plan layout. It was decided as an attempt to overcome an *impasse* moment which emerged during the political management of the process. Such 'accidental' initial condition did not hamper the carrying out of the remaining process, suggesting interesting perspectives on potentials and limitations of this approach in a real-life operational context. However, the extemporaneous nature of the decision did not allow a complete structuring from a formal and/or quantitative point of view. This resulted in a general impracticability of providing (or even searching for) sound demonstrations to emerging outcomes -as typically occurring when broad suggestions replace formal results. Therefore, the FCM model built up allows an interesting and intriguing, yet mostly qualitative level of reflections, while making a thorough evaluation of FCM methodology, as well as its comparison with other methods, fairly unfeasible.

In order to better address the potentials of such research, we will now explain (and contextually explore) some synthetic foundations of fuzzy-logic methodological framework.

2.2 Methodological foundations

In urban planning practices, the phase of collection and analysis of information plays a central role. Information is the result of a knowledge raising activity involving distributed knowledge agents in the given territory, as relevant stakeholders. As a matter of fact, a significant description of an urban system would often need far more detailed data than a human being could ever receive at once, understand and reprocess (e.g. data assimilation technique Berardi et al, 2016, Ward et al 2016). However, it is hard to describe the whole structure and behaviour of a complex environmental system through a plain mathematical model. Moreover, environmental complexity is able to raise uncertainty if we try to set elements, facts, knowledge etc. into classes using the traditional bivalent mathematical logic. For instance, Bayesian Belief Networks have shown several useful features to support decisionmaking under uncertainty for environmental issues (Pagano et al., 2018). Thus, in many cases, it seems more useful to represent environmental complexities graphically, showing the relationships between the elements involved. For such reasons, cognitive mapping (CM) arises as a suitable method to categorize and express structurally and manageably complex knowledge forms. Originally, Tolman (1948) introduced the CM concept to describe topological memorizing behaviour in rats. Later on, Axelrod (1976) used CM for representing social scientific knowledge in the field of decision theory. CMs are proposed as a means of modelling social and political group decisionmaking processes (Eden and Ackermann, 2011), for instance to involve stakeholders in building a comprehensive problem frame (e.g. Ackermann et al., 2014, Giordano et al., 2017, Howick et al., 2017) or to accelerate conflict resolution in multi-stakeholders settings (Ackermann et al. 2016).

Kosko (1986) extends the concepts of fuzzy logic to CM, introducing FCMs. Thus, FCMs represent the fusion of the advances of the CM approach with fuzzy logic theory. Although traditional CMs were able to lay out the mutual influences of system elements, they were unable to express the fuzziness of relations in many complex implementation contexts. The integration with fuzzy logic aims at overcoming such impasse.

Fuzzy logic was set up as an extension of traditional dual logic, thus providing a more reliable way of dealing with problems in which the source of ambiguity is the absence of well-defined criteria of class membership rather than the presence of random variables (Zimmermann, 2010). Fuzzy logic is a logic approach useful to describe real systems in which quantities are imprecise. It allows a more suitable handling of real-world aspects of pattern classification and information (Pappis et al., 2005).

By using FCM, Kosko makes CM more flexible and suitable to model real systems. Indeed, FCMs were conceived as an approach able to increase CMs expressive ability and applicability to more vague but real knowledge systems. In FCM, fuzzy logic and CM are combined for the representation of vague knowledge and the approximation of reasoning with uncertainty.

FCMs are fuzzy-oriented graph structures for representing fuzzy relationships between fuzzy concepts, so using fuzziness to allow hazy degrees of causality between hazy causal concepts. These variable concepts can be events, values, actions, trends, goals, moods, etc. (Kosko, 1986). The construction of FCMs, through a symbolic representation of knowledge, shows its fuzzy nature of construction methodology by relying on the exploitation of (typically expert) agents' knowledge on system behaviours (e.g. Groumpos, 2010, Giordano et al., 2017a). In general, expert agents identify factors that best describe the system and provide concepts able to explain each of them. These concepts are expressed on a normalized range denoting a degree of activation rather than an exact quantitative value (Aguilar, 2005). Then expert agents determine the relationship among concepts using a number of possible approaches: namely, they identify what elements of the system influence other elements, expressing relationship intensities by fuzzy weights (Groumpos, 2010).

Essentially, experts draw diagraphs among concepts, which correspond to values into an adjacency matrix, used to make inferencing. The mapping activity is an example of the fuzzification process in fuzzy logic (Aguilar, 2005). The fuzziness of a FCM occurs in the process of assessing intensity values on reciprocal effects between concepts, according to the expert agents' estimation and understanding of the system structure.

FCMs allow us to elicit the knowledge and experience in a symbolic manner and relate states, processes, policies, and values. FCM models can be used to support decisionmaking (Stylos, et al., 2008) and/or predictions about its future states (Stach, et al., 2008).

FCMs are a qualitative model that portray how a given system operates (Ozsemi & Ozsemi, 2004) through a network of interrelated concepts representing a belief system in a given domain (Kok, 2009).

Thus, FCMs can be used for individual decision-oriented representations. However, they are mainly used to build a shared vision of the decisional problem and to identify the values of the conflicting elements (Giordano & Vurro, 2010), when it is necessary to consider both expert and non-expert agents' knowledge.

FCMs have been applied successfully as a methodology to extract, depict and analyse different kinds of knowledge in participatory processes and group decisionmaking (Khan & Quaddus, 2004; Voinov & Bousquet, 2010; Kelly et al., 2013; Voinov et al 2016), in the context of generating consensus among different stakeholders (Pérez-Teruel et al., 2015), structuring environmental issues (Papageorgiou & Kontogianni, 2012; Gray et al., 2015; Vasslides & Jensen, 2016) and identifying different stakeholders' environmental risk perception for participatory modelling (Santoro et al., 2019).

The justification of the approach in this study is provided by the need for a framework that could help identify critical issues in data-poor environments (Lippe, 2011) and where local expert and non-expert agents' knowledge could provide fundamental information about the system description (Sanò, et al., 2014).

The FCM dynamic analysis leads the analyst to draw additional observations concerning the underlying system, which are not available in the static analysis (Stach, et al., 2010). FCMs are capable of forward chaining to answer *what-if* questions in scenario analyses, and the impact of the proposed action of the main elements can be simulated (Kosko, 1996).

From a formal perspective, an FCM is an oriented graph with nodes and arrows. Nodes represent variable concepts and the value of a node reflects the degree to which the concept is active in the system. The graph edges are the influences between concepts, expressed by either positive or negative signs, and the interconnection weights denote the strength of the connection between concepts (Aguilar, 2003, Aguilar, 2005).

Given a set of issues in a specific domain $(C_1, C_2, \dots, C_n)$, where n is the total number of concept-nodes, and given a set of oriented arcs (C_j, C_i) representing links between concept-nodes, then expert or non-expert agents are asked to fill the adjacency matrix e.g. within a participatory modelling technique. According to FCM practices (e.g. Kosko, 1986; Ozsemi and Ozsemi, 2004; Aguilar, 2005; Papageorgiou, and Kontogianni, 2012; Giordano et al., 2017a), each element of the matrix can take values in the fuzzy interval $[-1, 1]$. It is important to note that the relationships of the matrix elements are not necessarily reversible.

In an FCM, a discrete value of all the concepts can be recalculated at each step of a running cycle, according to the following equation. Each concept is related to a vector. A new value of the vector A_j^t shows the effect of the change of one concept on the other concepts (Aguilar, 2003). In a general formulation, it is calculated by the following rule:

$$A_j^t = f\left(k_1^i \sum_{j=1, i\neq j}^{n} A_i^{t-1} W_{ij} + k_2^j A_j^{t-1}\right)$$

A_j^t is the new value of the vector representing the concept C_j at time step t, A_i^{t-1} is the value of concept C_i at time step $t-1$ and A_j^{t-1} is the value of concept C_j at the time t. W_{ij} indicates the weight interconnection from concept C_i to C_j and f is a threshold function. Coefficients k_1^i and k_2^j must satisfy the conditions $0 \leq k_1^i \leq 1$ and $0 \leq k_2^j \leq$

1 and their selection depends on the nature of each concept (Stylos & Groumpos, 2004). Terms f, k_1^i and k_2^j have been described in literature (Groumpos, 2010).

The current paper aims to show the results of an application of the FCM methodology in the process of scenario-building in Taranto (Italy)

3 Cities, peripheries and decision support: the process of scenario-building in Taranto

Taranto is an important port city in the Mediterranean, with a territorial extension of about 220 sqkm and 200000 inhabitants. Its urban area, made of flat land and an internal lagoon partly faced by the city fabric, has a great environmental relevance. Historical significance is also important in Taranto, originally being a Greek Spartan colony founded in the first millennium BC, then suffering from a long hegemony of Rome that is today largely witnessed in cultural heritage. Nowadays Taranto economic base is industrial and its problems are connected with a decaying economy condition as well as with the dramatic impact on community sanitation caused by heavy pollution.

In 2014, the municipal administration started an evolving process aimed at replacing the older master plan drawn up in 1974, and the Polytechnic University of Bari research group was called to build strategies for future scenarios. Therefore, a SB methodology, focused on raising the distributed local knowledge of citizens, was used to design alternative visions for territorial development.

3.1 Scenario-building methodology

In order to delineate sustainable planning strategies, an interactive community-based process was set up to build future shared scenarios. The whole SB process was a hybrid expert/non-expert, formal/informal knowledge exchanging and raising activity. It was rather oriented to turn the complex social and environmental layout of the case study into a rich and articulated knowledge framework to support informed decisions by policymakers (Table 2).

Method	Step	Who	What	Where
Future workshop	1	Citizens	Focus-group (FG) sessions oriented to investigate criticalities, visions and possible strategies related to urban neighbourhoods	Taranto neighbourhoods
Fuzzy cognitive mapping	2	Knowledge engineers	Selection of 2 neighbourhood protocols as case studies (CV & SV)	Bari Polytechnic
	3	Expert agents	Clustering of the statements in CV & SV (Delphi iterations)	by email

	4	Knowledge engineers	Formalization of results for subsequent steps	Bari Polytechnic
	5	Expert agents	Identification of relations between statements with attribution of polarity and weights (Delphi iterations)	by email
	6	Knowledge engineers	Formalization of alternative future scenarios	Bari Polytechnic

Table 2. Outline of the SB process.

The stepwise process for the SB begins with meetings with citizens in Taranto neighborhoods, mainly relying on commonsense, experiential, non-expert knowledge. Then it proceeds through expert knowledge interaction and ends up with the comparative evaluation of alternative future scenarios. The first step was characterized by the involvement of citizens through focus-group (FG) sessions oriented to investigate criticalities, visions and possible strategies related to urban neighborhoods. Fifteen meetings took place and two of those sessions are taken into account in this study, aiming at comparing different peripheral contexts. The aim of FG sessions is to collect a knowledge base through the formalization of stakeholders' perceptions, behaviors and knowledge concerning the urban context, reaching shared visions and actions toward the implementation of future scenarios. FG sessions used the *future workshop* approach mentioned earlier. This process of participatory knowledge interaction is based on SB methodologies and slightly modified by Khakee (Khakee 2002b, Borri et al., 2006). People attending the meetings were first grouped around tables. Subsequently, they entered their views (under the form of written statements) about their neighborhood on graphical CM. Next, the workshops results were organized and formalized. Admittedly, the process was supposed to proceed toward fantasy and implementation phases, as agreed with Taranto administration. However, political problems –frequently affecting public arenas- slowed down activities and prevented the original process from being developed as planned.

Therefore, the phase of result formalization became an in-between activity oriented to feed a more formal, expert-based decision-support module for policy impact simulation. That module should be able to enhance local common knowledge along the planning process, even in an unplanned situation of insurgent constraints, clearly unsuitable to proper, extensive scenario-building processes. The idea was to investigate on a couple of degraded neighborhoods, characterized by environmental (*San Vito*) and housing/social (*Città Vecchia*) decay (figure 1). This phase was carried out using a FCM-based approach.

It was intended as an explorative effort, oriented to collect feedback about the suitability of the approach, so aiming at possibly enlarging and refining the process for future occasions. For this reason, the phase of selecting knowledge agents for this step was developed trying to involve people scientifically aware of environmental analysis, evaluation and planning. The group of agents was thus constituted by experts with technical academic backgrounds, gathered among scholars and researchers from local universities. This ensured a quick involvement of knowledge agents with appropriate and controlled levels of knowledge, even if partialized as formalized knowledge. On the other hand, a possible involvement of non-expert agents, with similarly appropriate and controlled levels of knowledge, would have implied the need for a much longer and more complex selection process, impossible to achieve in the short time required by the municipal administration at that process stage. Therefore, only expert agents, as earlier defined, where involved in the present stage. Specifically, adjacency matrices were built up, filled with the results of the critique phase. Expert agents identified directional influences within the values set $\{-1; -0.5; 0; +0.5; +1\}$ (-1 and $+1$ indicates respectively negative and positive relationships, 0 no relation, whereas -0.5 , $+0.5$ respectively denote the intermediate negative and positive values), using the *FCMapper* tool.

Figure 1. The studied neighborhoods in Taranto: *San Vito* and *Città Vecchia*, with SB data.

Within the case study, many statements expressing comparable meanings were clustered into 25 key issues, core concepts of each problem field, and further aggregated into 5 general areas. This result was attained through preliminary Delphi-like iterative evaluations provided by expert agents (table 3). The 25 items represented the input variables to build two adjacency matrices. The matrices and the corresponding maps were named according to the neighborhood location: *Città Vecchia* (CV) and *San Vito* (SV).

Code	**Aggregated issue**	**Key issue**
A_1	Community security	Crime rate and vandalism
A_2		Police control
A_3		Civic mindedness and respect of rules
A_4		Decorum and care of public spaces
A_5		Community involvement and assistance
B_1	Natural environment	Pollution of air, water and soil
B_2		Protection and enhancement of natural environment
B_3		Preservation and development of ecology
C_1	Infrastructures	Fuel-free mobility
C_2		Cultural and leisure facilities
C_3		Tourist amenities and accommodations
C_4		Maritime and coastal infrastructures
C_5		Maintenance of roads
C_6		Urban facilities and plants
C_7		Reuse and regeneration of abandoned buildings and urban areas
D_1	Urbanized and cultural environment	Renovation and maintenance of buildings
D_2		Landscaping and land fragmentation issue
D_3		Decay of environmental and cultural heritage
D_4		Degradation of social places and tertiary activities
D_5		Public/private partnership for projects development
D_6		Land regulations, formal limits and prohibitions toward speculation
E_1	Economy and society	Promote planning concerning local identity
E_2		Public budgeting toward a social-economic reinforcement
E_3		Develop and promote cultural heritage
E_4		Equalization of tax and services

Table 3. List of key and aggregated issues built by experts after the focus group sessions.

FCM approach allows knowledge acquisition also by using a structured Delphi-method iterative approach, as a number of matrices can be combined to one another (Kosko, 1996). This process of data refinement was carried out by the same group of expert agents above cited, who conducted a number of exchange tours of the same document, where concept relations, polarity and weights were iteratively modified to reach a final consensus (Licker, 1987). Agents used their formal scientific expertise to clarify and lay out relations among the various concepts in the matrix, as well as the related impact weights (Borri et al., 2013). Then, the adjacency matrices were translated into a FCM using the *FCMapper* tool. The maps elaborated by *FCMapper* point out the shared visions of the scenario, from possible to plausible alternatives. The *Pajek* graphical tool allows to exploit the positive or negative changes in the map through the different colors and nodes positions, coherently with the input file derived from the adjacency matrix elaborated by *FCMapper*. Thanks to the involvement of the stakeholder groups and the concepts elaboration through the FCM approach, the generation of ideas for concrete actions on the territory was reached

3.2 Toward a FCMapper-based support to decision process

Within the two case studies, specific measures of the adjacency matrix were analysed: high centrality, outdegree and indegree. In a graph, outdegree and indegree indices describe the aggregated strengths of connections considering respectively the row and column sums of absolute values of the related matrix. Centrality, represented through the nodes size, measures map complexity and shows how one variable is connected to other variables and what is the cumulative strength of the connections (Papageorgiou & Kontogianni, 2012). As said, the 25 items, input variables in the matrix, have been further aggregated by the same expert agents into 5 general areas, represented by different colours in the FCMs: A) Community security, B) Natural environment, C) Infrastructures, D) Urbanized and cultural environment, E) Economy and society.

In both case studies, a *what-if* scenario has been created using different initial vectors representing a proposed strategic action. Subsequently, each *what-if* scenario has been analyzed, in order to show the evolution of the FCM according to clustered trends. A preliminary study has been oriented towards elaborating a local specific scenario for each of the two neighbourhoods, building on collected items. They are an ecology-oriented scenario (‘eco-scenario’) for SV neighbourhood and a social-oriented scenario (‘socio-scenario’) for CV neighbourhood. The specific subjects of the two scenarios have been selected due also to the predominantly topic discussed in each area, i.e., an ecological-oriented debate in SV and a social-oriented debate in CV.

It is worth recalling here a similar clarification provided above, to avoid ambiguities. As said before, the singling out of key issues, as well as their aggregation into 5 issues, were carried out by ad-hoc expert agents. Therefore, the knowledge engineers of the process architecture (aka *ex-post* analysts of the process outcomes as well as paper authors) delivered the classification of results as formalized tables. The two scenarios discussed in this stage have been selected by the knowledge engineers, again, and proposed for the subsequent analysis through the FCM approach.

The 'eco-scenario' simulates the results of implemented policies that focus on the environmental issues of the neighbourhood. It concerns active/proactive policy actions in a framework of medium/long term planning effort and is oriented towards the environmental protection and the enhancement of local ecological resources. Eco-policies are supposed to be effectively implemented through community participation. On the other side, the 'socio-scenario' simulates the results of implemented active/proactive policies that focus on elements of urban regeneration and of social service improvement. It concerns regulations for the continuous improvement of infrastructure and services through their design, restoration and reuse.

Following the European conceptual tradition, Taranto inner city is considered as 'inner suburb', and the diffuse obsolescence of structures and infrastructures represents a major character of such analogical concept (Townshend, 2006; Robson, 1988). Under this enlarged perspective, the comparative analyses below will also represent an occasion to explore some potentials and limits of such conceptual enlargement.

Finally, it is important to underline that the choice to analyse the two scenarios has naturally resulted from the study of the adjacency matrices, according to the items with higher value of centrality and in/out degree index, showed by the tool. We worked using the most significant and central items and the interest in the social and ecological domain arisen.

3.2.1 Eco-scenario

The initial SV map shows high values of centrality index ranging from 22.50 to 14.00 in items B2, B3 (environment protection), E1, E2 (planning and design), D1, D2, D3 (building and natural decay), and an unconnected item E4 (figures 2 and 3).

In the eco-scenario initial state, only certain variables have been activated, namely A5, B2, B3, E1, E2, E3 (value = 1, yellow) and D3 (value = 0, light blue). Value 0 suggests that a given concept is not present in the system at a particular iteration, whereas the value 1 indicates that a given concept is present to its maximum degree (Papageorgiou & Kontogianni, 2012). Item D3 characterizes general abstract features of the model, such as the influence of “time" on its evolution. For these reasons, the research activity carries out simulation using direct and strategic elements of the urban system for plausible and feasible policies. In both scenarios, D3 value is 0.

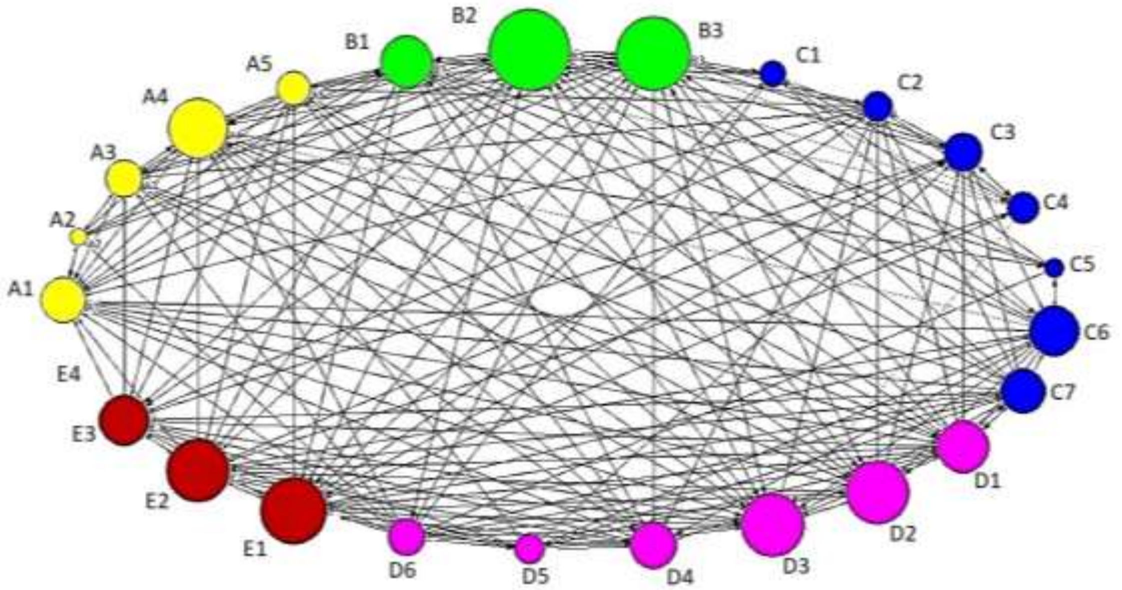

Figure 2. Initial state of the San Vito FCM, circular layout

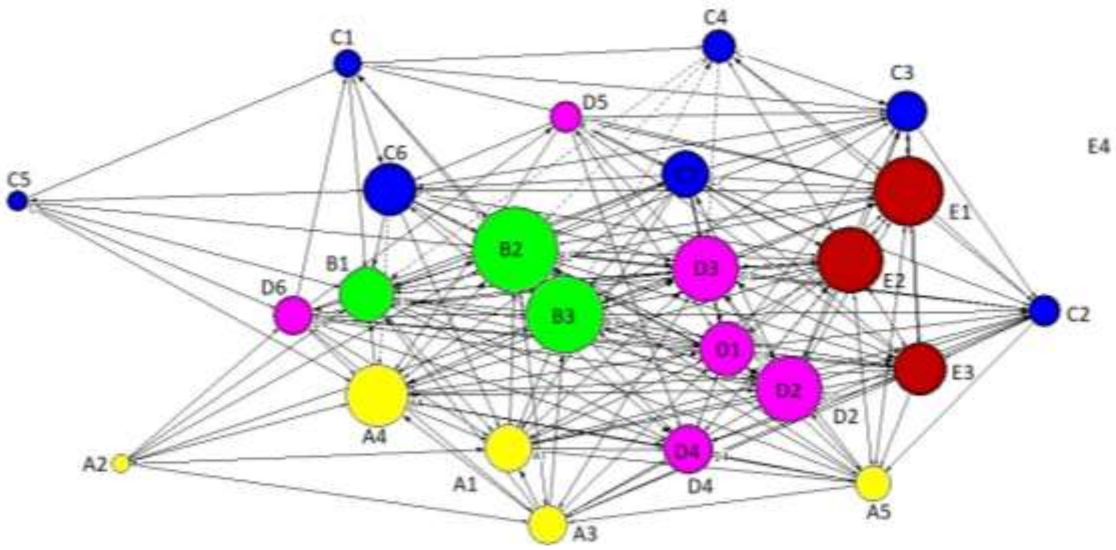

Figure 3. Initial state of the San Vito FCM, nodes with high centrality fixed

Looking at the items involved, eco-scenario is concerned with policies aimed at preserving and enhancing ecology and the natural environment (items B2 and B3). Suggested policies envisioned specific plans of action to defend the ecological features of the specific context, encouraging local-based economic growth (E1, E2) and the development of new cultural and artistic heritage (E3). Furthermore, the involvement of the community is a contingent domain with impact on ecological issues (A5). In the eco-scenario, efforts to compensate the natural degradation of the existing artistic and cultural heritage are supposed to be not disregarded by the decision maker (D3).

Eco-scenario maps were drawn using a partition derived from the activation of the defined vector with the *Pajek* visualization tool. In its final state FCM changes, as shown in table 4. The different colors represent the strength of item modification.

Item	**Variation**	**Colour**
A2	Medium impact - positive	Orange
A3	Strong impact - positive	White
C4, D1	Weak impact - positive	Violet
A1, B1, D2, D6	Very weak impact - positive	Dark Blue
C1, C2, C3, C5, C6 C7, D4, D5	Very weak impact - negative	Pink

Table 4. Final state of the *San Vito* FCM: partition derived from the activation of the defined vector in the eco-scenario

The final FCM results of the eco-scenario (figures 4 and 5) show a minimal increase of all problems concerning infrastructural development. An ecological policy action negatively influences all the stated issues of enhancing services infrastructures (items C1, C2, C3, C5, C6, and C7). Suggested policies are mainly concerned with the re-naturalization of the area while infrastructure-related actions remain in the background (e.g. excessive land consumption linked to the expansion of roads and parking areas). The implementation of eco-policies has not affected social or touristic infrastructure (C2, C3). On the other hand, the lack of attention towards infrastructure has had a negative impact on urban ecological elements such as fuel-free mobility, bicycle traffic, electrical public transport (C1) that can minimize pollution in their life cycle use. The element rising in the same direction of the eco-policies is coastal infrastructures development (C4), since it is a virtuous element of the local context, as deduced in the focus group sessions.

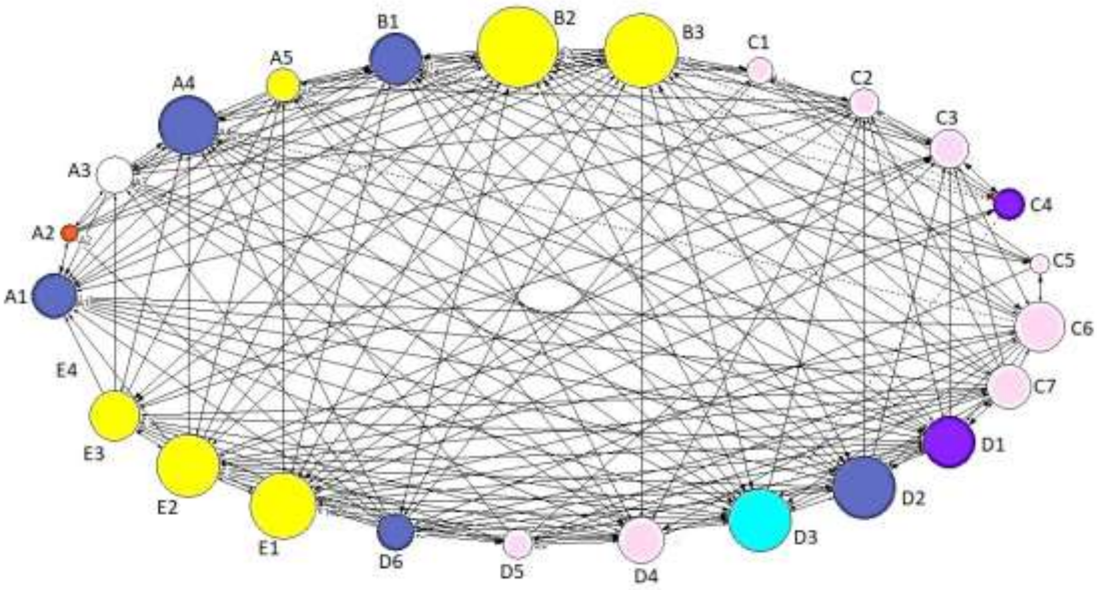

Figure 4. Final state of the *San Vito* FCM: central layout

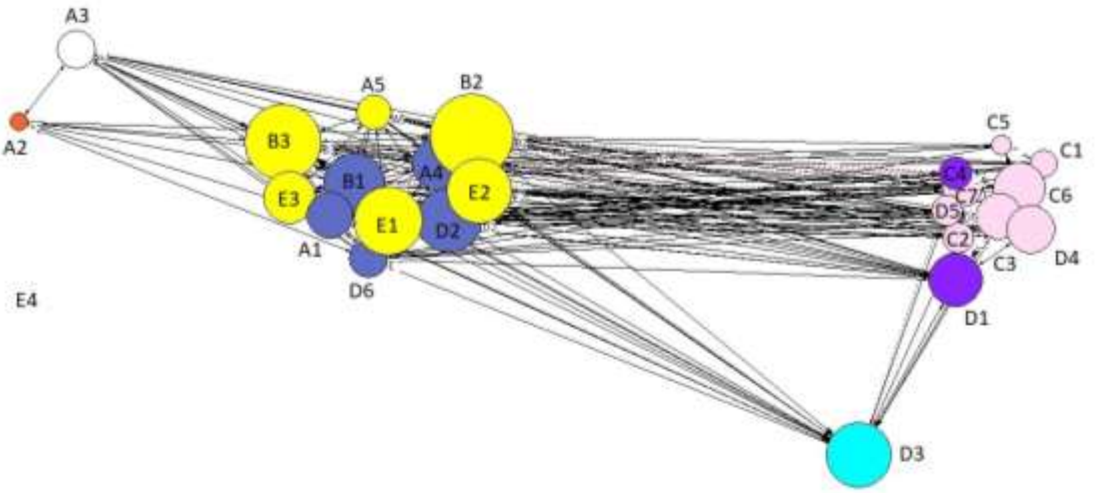

Figure 5. Final state of the *San Vito* FCM: evolution according to the cluster

The idea of improving environmental awareness points indirectly to the issues of community security and positively affects the social sector (area A). In this regard, the values of items concerning urban safety problems decrease (A1 and A2). The overall respect of rules, decorum and carefulness of public spaces (A3 and A4) increases.

An interesting result can be observed in area D (urbanized and cultural environment). Thanks to community environmental awareness (A5), the eco-scenario seems to show positive return on the management regulations of local resources (D6). Even if the scenario does not operate on the degradation of urban green areas, indirect positive impacts have been observed. Environmental rehabilitation policies give benefits in the management of land fragmentation and in the redefinition of urban spaces. In the end, the eco-scenario shows a deficiency in public-private planning (D5) and a limited growth of tertiary sector (D4). This behavior could be explained through the difficulties manifested by small and medium local companies to adopt green economy business dynamics

3.2.2. Socio-scenario

In the initial state of the second case study, the centrality index of items D3, E2, E3 is significantly high (28.00-19.50), whereas C5, C6, D6 have lower values (8.50 – 15.00). Items A3, A4, B2, C7 and E4 are unconnected (figures 6 and 7).

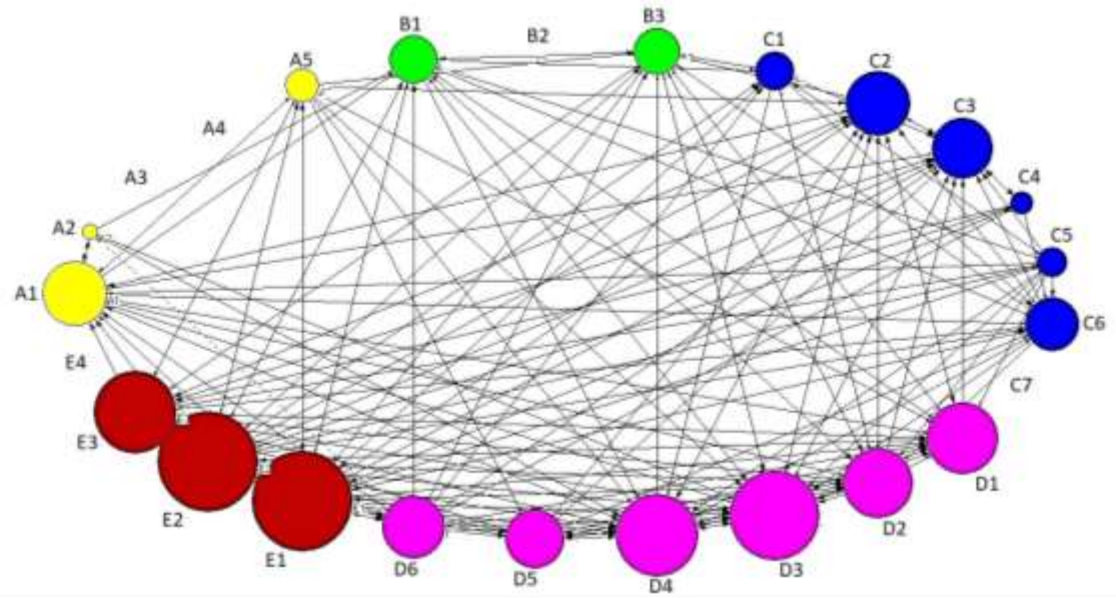

Figure 6. Initial state of the *Città Vecchia* FCM: circular layout

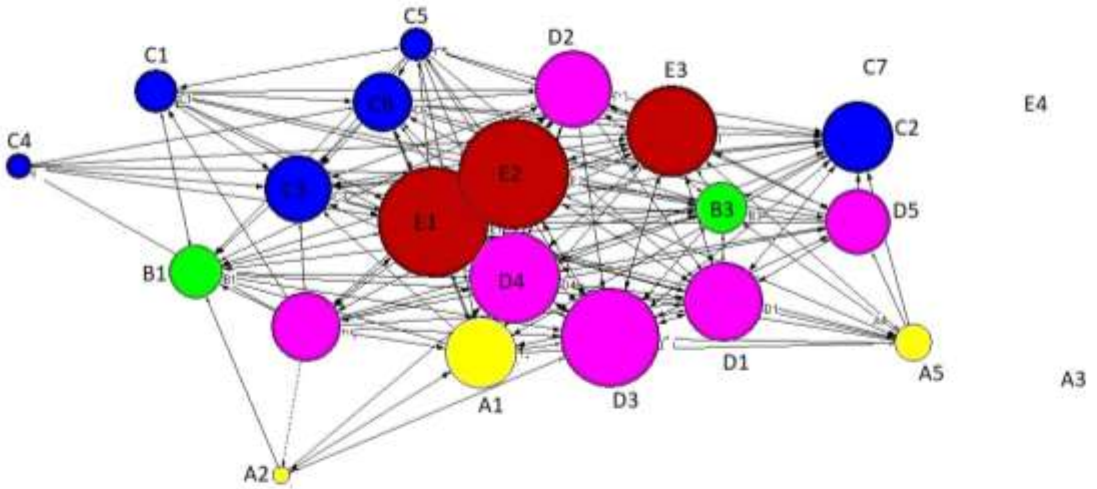

Figure 7. Initial state of the *Città Vecchia* FCM: nodes with high centrality fixed

In the initial state of socio-scenario the significant values of the activated vector are C5, C6, D6, E2, E3 (value = 1, yellow) and D3 (value = 0, light blue). Socio-scenario points out suitable planning actions for policies aimed at enhancing urban environment and the local-based economic and cultural growth (E2, E3). It is applied to urban networks and to citizen services, in order to improve the obsolete infrastructures of the neighborhood (C5, C6). Socio-policies act to reduce a rapid and anarchical urbanization (D6). Besides, in the socio-scenario, the decision-maker has not considered the natural degradation of the existing artistic and cultural heritage (D3). The final state of the socio-scenario FCM shows the following structure (figures 8 and 9). Specifically, table 5 explains the system evolution.

Item	**Variation**	**Colour**
A5, D2	Weak impact - negative	Pink
C1, C4	Very weak impact - negative	Blue
A1, C2, C3, D4, E1	Very weak impact - positive	Dark Blue
B1, B3	Weak impact - positive	Violet
A2, D5	Medium impact - positive	Orange

Table 5. Final state of the *Città Vecchia* FCM, partition derived from the vector modification in the socio-scenario

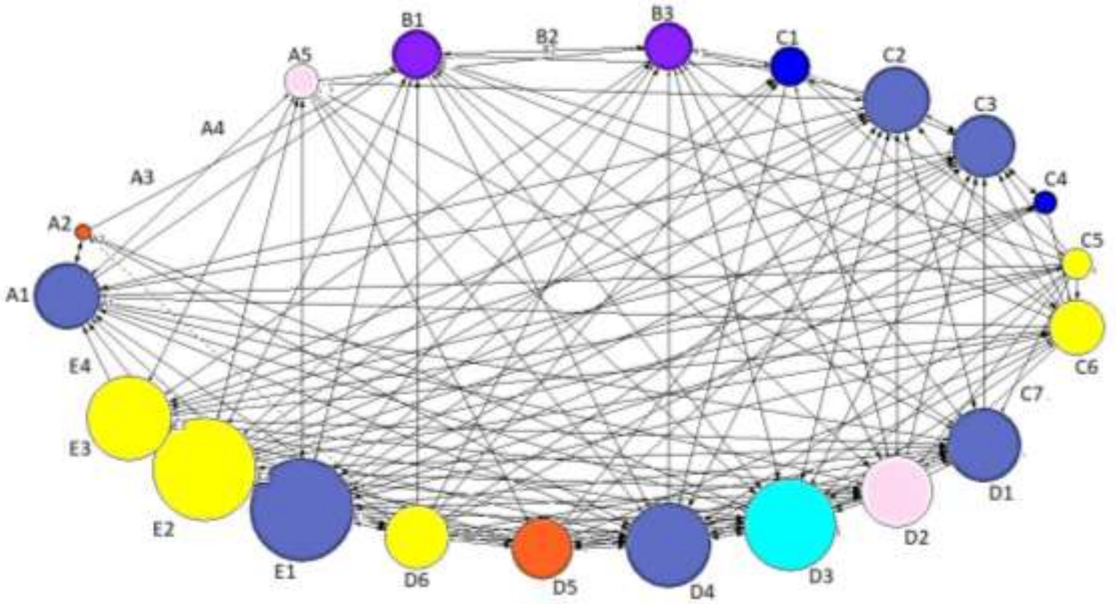

Figure 8. Final state of the Città Vecchia FCM: central layout

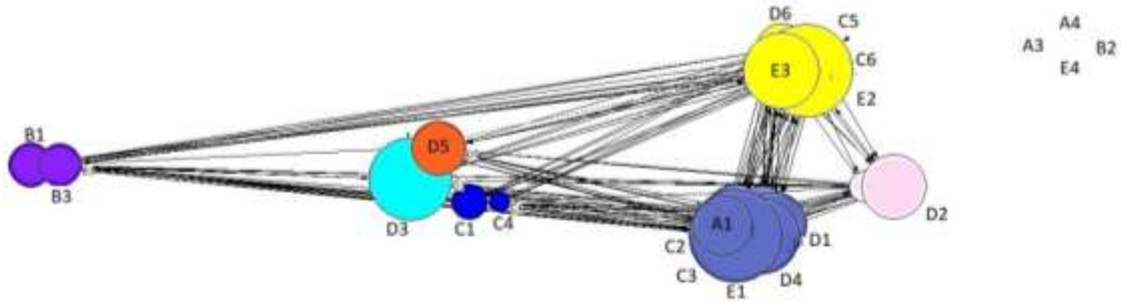

Figure 9. Final state of the *Città Vecchia* FCM: evolution according to the cluster

The resulting FCM of the socio-scenario shows increased values on item E1 related to the encouragement of plans concerning local community identity. It represents the connection between the specific attributes of the 'inner suburb' and the characteristic needs of the studied urban area. The socio-scenario renovates social and cultural structures (C2) and touristic infrastructure (C3), thus reducing the decay of the place for community activities (D4). It has superficial impact on social domain (A5). The implementation of socio-policies is positively reflected on community security (A1 and A2), thanks to social involvement, local economic investments and the empowerment of citizen networks. The social efforts make the stakeholders feel responsible in the defense of the community's urban heritage. On the other hand, policies concerning urban renewal reduce possible actions to support underprivileged families in the neighborhood (A5). The values of ecological items evolve positively through the promotion of the ecosystem preservation (B1, B3). Innovative actions for the rehabilitation of physical urban elements take into consideration the sustainable and ecological rehabilitation of city spaces, (e.g. facilities for using renewable resources, the promotion of "zero energy" buildings).

Concerning area C (infrastructures), there is a positive effect on the availability of cultural spaces for citizens (C2) and tourists (C3) and an increased value of the correspondent items. These elements directly benefit from a policy of regeneration of built environment and of urban services. On the other hand, items C1 and C4 cannot achieve benefits since they require ad-hoc action-policies (e.g. C1 requires specific strategies for the improvement of obsolete public transportation).

Area D (urbanized and cultural environment) reports a twofold result. On one side, the value of the item concerning the redefinition of urban spaces and of green areas (D2) decrease. On the other side, items D1, D4 and D5 display receptivity to public/private social interventions. They are related to a widespread process on existing buildings.

Socio-policies have positive impact on private building stock (D1), on tertiary activities (D4) and on public/private investments for neighborhood regeneration (D5).

4 Discussion

As previously mentioned, SB has represented a structured arena of mutual-learning and knowledge-raising interaction among knowledge agents in a community, oriented to support decisions in sustainable development policymaking and planning. Scenarios may envision possible development alternatives, either mutually exclusive or potentially integrated for decisionmakers. The discretionary power of decisionmakers is still important, but the high level of knowledge and community agents' involvement raised by the process represents a remarkable counterbalancing power *per se*. A significant issue of this approach is the considerable time needed to build the knowledge base (i.e., future scenarios), often reputed too costly by public administrations in terms of time and financial resources (Khakee et al., 2002a).

Another shortcoming related to the same problem is a frequent interruption and abandonment of the method, due to pressures exerted by lobbies on decisionmakers or to insurgent time constraints. On the drawbacks of *planning participation* there is a long and evolving literature, which considers such problems as common in public management (Forester, 1999). Issues particularly range from the role of social and financial/economic environments in putting pressure and constraints on the limited electoral mandate of mayors, to the little time available to stakeholders for participatory engagements during normal work time (Hague, Jenkins, 2005; Friend, Hickling, 1997). Moreover, there is also a well-established literature on the possible risk of rhetorical and demagogic management of results for consensus management (Friedman 1987; Forester, 1999). To limit these problems, a growing trend today aims to construct processes using explicit models of collection of structured knowledge, possibly formalized (agent-based systems, ontology models etc.) and oriented to internalize these forms of normal socio-environmental complexity without reticence (Camarda, 2010). Taranto case study case was a useful occurrence just in this concern, so determining the need to find an alternative approach able to preserve the database already developed while completing the decision-support process. That occurrence enabled us to test a FCM approach, which proved to be helpful in this case. In fact, a major feature of *FCMapper* tool is the structuring of local knowledge for a bottom-up decisionmaking process, starting from a de-structured or semi-structured database (e.g., Borri et al., 2013).

Visions built on SB-FCM integrated approach were the basis for assessing the effectiveness or suitability of the FCM method in a real context. The first vision concerns environmentally sustainable policies finalized in the ecological scenario of SV. A particular interest is played by the typical dimensions of sustainable development, actually occurring in manifold domains. Following consolidated literature (e.g. Newman and Jennings, 2012), there are dimensions of economic sustainability, environmental sustainability (intended as the preservation and valorization of natural, historical, cultural assets), social sustainability (involving particular attention to welfare, well-being, ethics and security) (Table 6).

TARANTO *San Vito*
• Planning for limited transport infrastructures as they have impact on the environment • Enhancing sea tourist and fishery infrastructures • Increasing maintenance, cleaning and surveillance of public spaces against law violation and vandalism • Decreasing the degradation of social places and services • Decreasing the degradation of green areas, regenerating dismissed areas and fighting land fragmentation • Discouraging land regulations, formal limits and prohibitions toward speculation, being granted by improved environmental awareness of people • Lowering pollution of air, water, soil as an outcome of improved environmental awareness of people

Table 6. Taranto eco-scenario, *San Vito*

The vision mostly shows interconnected issues, as if they are giving mutual significance and finalization to one another. An accent is given on environmental awareness, boosted by the disaffection about industrial impacts, as structural ineludible means of preventing speculation and degradation, beyond traditional regulations and constraints.

The second vision is a picture of a socially concerned city finalized in the social scenario of CV. Differently from the previous one, in CV social issues are mixed with (and somehow oriented to) urban regeneration. The scenario gives a structural importance to regeneration issues, particularly physical regeneration, in terms of buildings, spaces, services, and environment. Another concern is on mobility and transportation, claiming for a planning approach, rather than the mere improving and adjusting approach. Basically, this issue seems clearly linked to the operational needs of socio-economic development of Taranto inner city (Table 7).

TARANTO *Città Vecchia*

• Reducing degradation of green areas and land fragmentation • Enhancing social and cultural structures and tourist infrastructures • Reducing decay of spaces and places for community activities • Encouraging plans concerning local identity • Lowering criminality and vandalism • Promotion of the ecosystem preservation • Need of mobility planning • Involving private investors in urban regeneration

Table 7. Taranto socio-scenario, *Città Vecchia*

In general, the hybrid SB process in Taranto has driven to single visions and to solutions for single issues, rather than to full strategies. Certainly, this is not an expected outcome of a scenario-building process, typically geared to the fine-tuned building-up of full strategic alternatives toward a more thoroughly informed decision by decisionmakers. However, the process did not actually result in a bunch of mutually-exclusive, disjointed issues in its final picture. Rather, an evident knowledge-to-action orientation characterized all the steps, thus tendentially revealing an inherent coherence of issues in both SV and CV scenarios, boosted by a strong place-based implementation perspective. Further, it is rather surprising that a convincing, tumultuous environmental awareness has developed in the community, about physical but also economic potentials as well as risks. Beyond typical concerns about employment and social issues, new issues have appeared, concerning ecosystem, natural and urban landscape, air and water quality but also life and resource heritage. As a whole, the interaction carried out in the problematic contexts of the city largely confirms the growth of awareness about the multiplicity of problems and potentials, as concepts increasingly embedded in the community cognitive patrimony. On the other side, scenarios seem to lack structural reference to cultural and historical issues. As mentioned earlier, Taranto has a millennial tradition of artistic and cultural heritage, able to raise people's sense of identity and community, as often argued (Matvejević et al., 1998; Smith, 2013). The apparent understatement of such issues seems rather puzzling under this condition, suggesting further reflection.

In particular, protocols show heritage and millennial cultural history as often embedded concepts in community discourses. Moreover, the fact that such important issues somehow slip out of the clustered mapping made by *FCMapper* might be due to the limitations of a logical-mathematical approach, which observes and manages concepts as they appear in the protocols and not for what they hide inside -a semantic/analogical prerogative which is largely exclusive of human reasoning still today.

5 Conclusions

The present work has been carried out within a broader research field dealing with knowledge management models to support decisions in public planning and policymaking. In particular, the role of fuzzy cognitive maps (FCMs) as an environmental modelling approach has been explored in urban problematic contexts. While in our previous works the suitability of this model had been checked in decisions concerning one specific objective, the present study is oriented to the broader theme of urban policymaking within a planning process (Borri et al., 2013).

Generally, problematic areas show a complex layout that is reflected in the complexity of the decisional process of policymaking: therefore, complexity emerges as an embedded limitation of the planning process (Newman & Jennings, 2008). In this context, a FCM-based approach may be used to integrate decisional support features, because its explorative layout can simulate scenarios by using the ad-hoc sensitivity analysis module. In fact, firstly, it would be useful for knowledge elicitation and, secondly, it could help to show the chain of interdependencies between different concepts expressed by relevant agents of the community. Lastly, this approach could support the translation of this sort of multi-source and multi-form knowledge into structured spatial reasoning, that is typically used to generate master plans.

The case-study of Taranto master plan has represented the framework of this process, in which a SB layout was set up toward the definition of alternative development strategies particularly in problematic urban areas. Some stages of the process have been driven using FCM analysis, modifying the traditional *future workshop* approach to deal with time shortage and overcome some political drawbacks during the management of the process. Some results have been shown and discusses throughout the present work. The two neighbourhoods in which FCM has been adopted showed a scenario of ecological-oriented policies (in SV neighbourhood) and a scenario of socio-economic urban regeneration policies (in CV). Using a FCM-based approach, scenarios have *quali-quantitatively* represented conceptual (social, economic) and physical fields of the impacts of ecologically-inspired (in SV) or regeneration-inspired (in CV) policies. In SV, an accent is put on environmental awareness, boosted by the disaffection about industrial impacts, being structural means of preventing speculation and degradation, beyond traditional regulations and constraints. CV scenario gives a structural importance to regeneration issues, particularly physical regeneration, in terms of buildings, spaces, services, environment, clearly linked to the operational needs of socio-economic redevelopment of Taranto inner city.

The quality of outcomes has proved to be dependent on the degree of causality linkages among contextual issues and features required by the FCM-based approach, i.e., the higher the causality, the better the outcome. As ecological and social scenarios evoke issues that are expressions of the inherent complexity of the environmental domain, it could be expected that causal links are similarly complex, distributed and not polarized. This may mean that a FCM approach is significant when focusing on selected urban parts, but is arguably less suitable to broad planning process as it might cause low quality results.

Overall, FCM application has produced a number of significant benefits, able to express interesting features in this case study. From a general standpoint, the value added of FCM emerges, as a tool to support the analysis of problems characterized by high (social, economic, environmental) uncertainty, when different forms of expert/non-expert knowledge are involved and need to be integrated. From a knowledge organization viewpoint, it helped the structuring of local knowledge for a bottom-up decisionmaking process, starting from a de-structured or semi-structured database built up in an earlier stage. In turn, this condition favoured the synthesis and the highlighting of visions and objectives, which is the necessary structural reference for drawing a spatial plan. As a particular positive aspect induced by that circumstance, FCM brought out more clearly the strategic role of natural environment as a key resource for future strategies to be carried out in Taranto -despite a historic environmental scepticism by politicians (Camarda et al., 2014).

Moreover, the layout produced by using FCM showed a significant flexibility in the generation of scenarios, even with a limited spatial and temporal impact. This is something different from traditional scenario building, strongly oriented to long-term strategic alternative for far-future scenarios (e.g. Khakee et al., 2000, 2002a). Yet, this approach has allowed a better area-based focus with a future orientation. On the other side, as mentioned above, FCM seems to be more suitable to specific policies than to wide-range strategies. This is true, although intriguing insights are nonetheless evident, underlining an inherent feature of FCM models for short to medium-time decisionmaking.

From a language formalization point of view, the consideration of FCM-based approaches seems to help a more structured formalization of participants' knowledge, which is important for an inclusive policymaking perspective. This is worth noting, particularly in contexts with knowledge complexity such as urban peripheries. In this sense, a FCM-based integration might help overcoming some existing limitations of participatory planning, namely in terms of effective knowledge-to-action planning decisions in problematic urban areas.

In the end, a thorough consideration on the use of a FCM-based approach to help managing socio-economic and environmental knowledge, in order to support public planning decisions in complex urban environments, is not completely final at this stage. The hybrid SB-FCM experimentation has certainly resulted in interesting outcomes, particularly in situations of time constraints, putting value on the knowledge elicited and enhancing data structuring and formalization. Yet this might not be enough *per se* to guarantee the quality of knowledge raised -that still depends on proper, often extensive time needed for inclusive processes. Moreover, because of the unplanned inclusion of the FCM module in the process, the general model could not be completely structured under a formal and/or quantitative point of view. This resulted in an intriguing, yet mostly qualitative level of reflections that characterized the whole evaluation discussion. For example, the overall mutual-learning achievement, commonly embedded in such knowledge-intensive processes (Khakee et al., 2002a), was only qualitatively confirmed through an *ex-ante* vs. *ex-post* comparison of conceptualizations. Also, this condition ended up making a thorough evaluation of FCM methodology, as well as its comparison with other methods, fairly unfeasible.

In general, the work should be considered as an interesting pilot study aimed at putting the foundations for subsequent, more articulated activities. Starting from the outcomes of this experience, further investigation and new experimentations will be certainly useful to achieve more formal and quantitative models, as a more structured contribution for the research perspectives of knowledge-based planning support systems.

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