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Ambiguity in decision-makers' information needs: from barrier to enabling factor for urban adaptation to climate change

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Abstract: There is a mounting international interest about how to address the implications of climate change for urban areas. The availability and sharing of "good" knowledge and information is a key prerequisite for a successful planning in cities, specifically if we consider climate change adaptation as a collective decision process. This raises the importance of the availability/usability of proper "planner/user friendly" interfaces – i.e. climate services – helping decision makers to interpret and translate the available information into adaptation decisions, and to facilitate the sharing of this information within the interaction network in which the different actors are embedded. Evidences demonstrate that ambiguity in problem understanding could represent a barrier to the actual use of climate services in urban adaptation, because it could lead to different information needs. Ambiguity in problem framing could affect the connection between information production and decision process. The activities described in this work aimed at facilitating the use of climate services as tools to enable the collective decision-making process for urban adaptation in Helsinki. To this aim, two main issue have been addressed: i) the ambiguity in problem understanding; ii) the complexity of the interaction network involving the different decision-actors. Two main approaches were implemented, i.e. Problem Structuring Methods (PSM) for ambiguity analysis and Social Network Analysis (SNA) for unravelling the complexity of the interaction networks involving the different stakeholders. The results of this integrated approach have been used to develop and experimentally test a collective decision making platform for urban adaption.

***Keywords**: Ambiguity analysis, Information needs, Climate service, Urban planning for adaptation.

1. Introduction

The governance structures allowing the mainstreaming of climate change adaptation in urban planning have been extensively investigated in the scientific literature. Evidences demonstrated that, in order to be effective, strategies for coping with climate change at urban level require not only a deep understanding of the main phenomena to be addressed, but also an unprecedented level of cooperation between different levels of institutional government and the private sector.

Adaptation processes involve the interdependence of agents through their relationships with each other, with the institutions in which they reside (organizational structures), the knowledge they use and the resources based on which they depend (Adger, 2003; Castán Broto & Bulkeley, 2013). Many potential risks related to climate change necessarily involve intervention and planning by the institutional actors, yet adaptation strategies are equally dependent on the ability of individuals and communities to act collectively (Adger, 2003). Collective decision making is a central feature in the policy process for urban adaptation (Cochran & Teasdale, 2011).

Many efforts have been carried out aiming at enhancing collective decision-making processes through a more effective information sharing process involving innovative technologies in urban adaptation for climate change. Nevertheless, these attempts largely failed because they neglect the role of cultural heterogeneity in affecting one of the most important phases in the process from-information-to-decision, i.e. the sense-making phase (Wolbers & Boersma, 2013). This phase allows decision-actors to select the most important information for supporting their decision process, to gather it and to provide it a meaning. This phase is not neutral, but commensurate with the perspectives and frames held by the actors making the decisions. Therefore, differenced in problem frames could hamper the flow of information and, hence, the collective decision-making for climate change adaptation. Analyzing ambiguity becomes of utmost importance. Ambiguity refers to the degree of confusion that exists among actors in a group for attributing different meaning to a problem that is of concern to all. In a management situation, it indicates that there are discrepancies in the way in which the situation is interpreted. It originates from differences in interests, values, beliefs, background, previous experiences and societal position among the actors. In multi-actors setting the presence of ambiguity may have diverse implications. On the one hand, a diversity in frames can offer opportunities for innovation and the development of creative solutions (Brugnach and Ingram, 2012). On the other hand, the presence of ambiguity can result in a polarization of viewpoints and the incapacity of a group to create a joint basis for communication and action (Giordano et al., 2017). It has been suggested that divergent frames can still yield organized collective action when the interaction formats (i.e., communication and interaction behaviors actors use) are sufficiently aligned (Dewulf et al. 2009).

In order to be actually effective in supporting urban planning for adaptation, climate services (CS) should have a twofold role. On the one hand, CS should provide *actionable* information to the decision-makers. That is, CS should contribute to fill the gaps between information and actions. On the other hand, CS should contribute to align the interaction frames enabling the effective information sharing process.

Starting from these promises, this work aims at providing responses to two main research questions: i) To what extent differences in information needs, which are unavoidable in an institutional settings such as the urban planning, could represent an actual barrier to urban planning for adaptation? ii) What is the most suitable CS structure in order to create interaction mechanisms involving the different stakeholders for effective urban planning for adaptation? To this aim, a multi-step methodology, based on the integration between Fuzzy Cognitive Mapping (FCM) and Social Network Analysis (SNA) has been developed and implemented to support the co-design of a CS for urban adaptation in Helsinki. Th

2. Materials and Methods

2.1. Fuzzy Cognitive Maps for information needs definition

The implementation of the FCM in this work aims at assessing to what extent divergences in problem framing could also lead to barriers hampering the adoption of climate services. To this aim, we firstly related the stakeholders' information needs (i.e. what kind of information each stakeholder needs in order to solve a certain problem and/or take a decision) to the problem framing. Secondly, we analyzed in which condition discordance over adaptation-related information may result in discordance over climate services.

Fuzzy Cognitive Map (FCM) can be considered as a model which is as close as possible to the cognitive representation made by decision makers. Thus the model can be considered as a "mirror" of the causes and effects that are inside the mind of decision makers (Montibeller et al., 2001; Kok, 2009). FCMs can simulate the cause – effect relationships between the main variables in the model. The FCM comprises concepts representing the key elements of the system, joined by directional edges or connections representing causal relationships between concepts. Each edge is assigned a weight which quantifies the strength of the causal relationship between two concept (Kosko, 1986).

The first phase in the implementation of the FCM to support the mainstreaming of climate service in urban planning was meant to elicit and structure the different stakeholders' problem understanding. The first issue to be addressed concerned the selection of the experts to be involved in this phase. In order to minimize the selection bias and the marginalization of stakeholders (Ananda & Herath, 2003; Reed et al., 2009) a top-down stakeholder identification practice, which is referred as "snowballing" or "referral sampling", was implemented (Harrison & Qureshi, 2000; Prell et al., 2008; Reed et al., 2009). The selection process started with the actors mentioned in the official protocol of interaction for urban planning, i.e. the decision actors whose main responsibility is to develop urban strategies and plan for adaptation. The preliminary interviews carried out with these agents allowed us to widen the set of stakeholders to be involved.

The individual FCM were developed through semi-structured interviews. The framework for the interviews is described in the annex. The interviews aimed at collecting the stakeholders' perceptions about the cause-effects chains affecting the impacts of climate change at urban level, and the potential solutions. In order to use the results of interviews for the FCM development, a "means-ends" hierachical approach was adopted in this phase. The interviewees were, thus, required to describe the main climate change impacts at urban level in terms of risks. Then, they described the primary (direct) and secondary (indirect) impacts of those risks. The main causes of the system vulnerability were also descibed by the involved stakeholders. Finally, the interviewees were required to describe potential and/or existing

strategies to facilitate the adaptation of the urban system to climate change. The role of climate-related information was discussed as well.
The interviews were analyzed in order to detect the keywords in the stakeholders' argumentation – i.e. the variables in the FCM – and the causal connections among them – i.e. the links in the FCM. The following figure shows how the stakeholders' narratives, collected during the interviews, were translated into FCM variables and relationships.

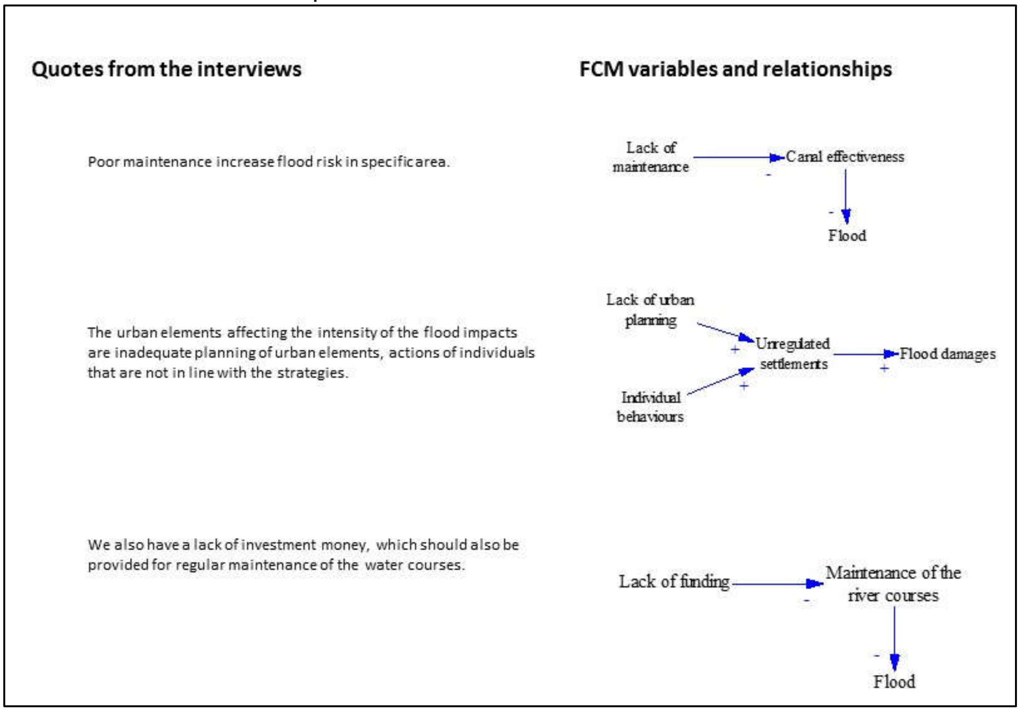

Figure 1 Translating quotes from the stakeholders' interviews into variables and relationships of FCM

The FCM developed referring to the stakeholders' interviews were used to infer the users' information needs. For a more detailed description of the FCM developed in the EU-MACS case studies, please, refer to the following sections. Two sequential analysis were carried out. Firstly, the FCM were analysed in order to detect the most important elements in the stakeholders' problem understanding, the so called "nub of the issue" (Eden, 2004). Secondly, the FCM capability to simulate qualitative scenarios were used to assess the expected impacts of climate related information on the stakeholders' problem understanding.
Concerning the first analysis, FCM centrality degree was assessed. The basic assumption in assessing the centrality degree of the variables contained in the FCM is that the more central the variables, the more important the concept is in the stakeholder's perception. Taking into account that the meaning of a variable in a FCM depends on its explanations and consequences (Eden, 2004), the centrality of each concept can be assessed analyzing the complexity of the surrounding perceived causal chains.
The individual FCM were then used to define the stakeholders' information needs. To this aim, different scenarios were simulated using the individual FCM. The Business-As-Usual scenario (BAU) was simulated running a FCM process ((Kok, 2009) with an initial state vector A0, with all variables set to 0, besides those related to Climate change. In order to assess the impacts of information availability on the stakeholder's problem understanding, the value of the connected variable is changed in the initial state vector, and the change of values of the most important elements (i.e. those with a high centrality degree) was evaluated. The comparison between the BAU and information-related scenarios allows to simulate the impacts of the information availability on the decision-actors capability to take decisions for adapting the urban system to the climate change (figure 2).

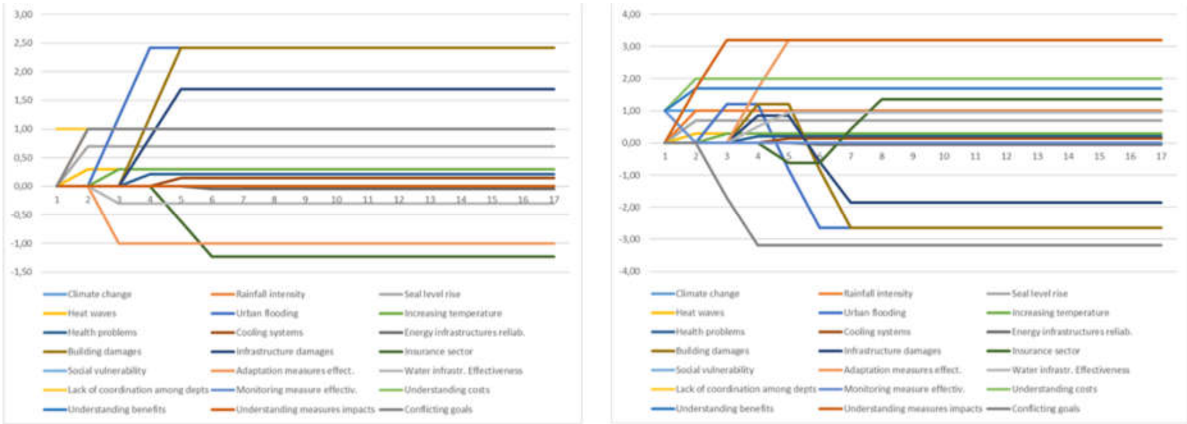

Figure 2 State of the FCM variable in the BAU scenario (a) and in the information-available scen453ario (b)

The basic assumption is that the higher the impacts of information availability on the most central variables in the stakeholder's problem understanding, the more crucial the information for addressing climate adaptation measures (information needs). Individual analysis were carried out in order to elicit and compare the stakeholders' individual information needs. This analysis allowed us to identify complementarities in information needs, and differences that could lead to barriers to CS mainstreaming in urban planning.

2.2. Social Network Analysis in urban planning for adaptation

Decision-making actors do not operate in a vacuum. Social interactions can alter choices. The main scope of this phase is to analyze the way the different stakeholders interact each other an exchange information, knowledge, resources in order to carry out shared adaptation tasks. Social network analysis (SNA) can help understanding how and why the actors behave the way they do, through the analysis of structural patterns of relations. Moreover, it provides valuable insights to ambiguity in problem understanding and framing, and how uncertainty is dealt with. The basic assumption behind the role of social network analysis in climate change adaptation is that the structural patterns of relations in networks influence the social processes (Borgatti, 2006). Social network mapping can support the identification and analysis of barriers to cooperation and collaboration (Bodin and Crona, 2009).

Networks topologies can be analyzed at the node-level focusing on institutions or actors. The centrality of an actor allows analysis of the role she/he can play in the network as a bridge that connects the others. These actors facilitate the flow of knowledge and information within the network. Central actors can be potential agents of change, facilitating the implementation of policies for climate change adaptation.

In this work, SNA has been implemented to make explicit both the formal and informal networks of interactions, allowing urban planners and risk managers to better comprehend its complexity and enhance their capabilities to enable collective decision processes. Among the different methods available in the scientific literature for modelling and analysing the social networks (e.g. Borgatti, 2006; Ingold, 2011; Lienert et al., 2013), the Organizational Risk Analysis (ORA) approach has been implemented in this work (Carley, 2002). The underlying assumption in ORA is that an organization could be conceived as a set of interlocked networks connecting entities such agents, knowledge, tasks and resources (Carley, 2005).

In order to implement the ORA approach, we considered the whole set of actors involved in urban planning and climate-related risk management as one heterogeneous organization (Leskens, Brugnach, Hoekstra, & Schuurmans, 2014). The interlocked networks can be represented using the meta-matrix conceptual framework, as shown in the following table.

	Agent	**Knowledge**	**Tasks**
Agent	*Social network:* map of the interactions among the different institutional actors in the different urban planning phases	*Knowledge network:* identifies the relationships among actors and information (Who does manage which information? Who does own which expertise?)	*Assignment network:* defines the role played by each actor in the urban planning phases
Knowledge		*Information network:* map the connections among different pieces of knowledge	*Knowledge requirements network:* identifies the information used, or needed, to perform a certain task in the urban planning.
Tasks			*Dependencies network:* identifies the work flow. (Which tasks are related to which)

Table 1 Meta-matrix framework showing the connections among the key entities of social network (adapted from (Carley, 2005))

Following the graph theory, the weights in the matrixes were used to represents the strength of graph edges, while rows and columns were labelled by graph vertices. Indeed, a graph $G =< V, E >$ consisting of a set of vertices (nodes) V and a set of edges (arcs) E, can be represented by an adjacency matrix $A = |V| \times |V|$.

In this work, the map of the network was used to analyze and unravel the complexity of interactions, allowing the identification of the key elements in the network and the main vulnerabilities. To this aim, graph theory measures were implemented. Table 2 describes the measures adopted for the identification of the key actors, their definition according to the graph theory and the meaning in urban planning for climate change adaptation. For a detailed description of the graph theory measures for the analysis of the networks, a reader could refer to (Freeman, 1978; Carley et al., 2007)

Network	Network measure	Assessment	Meaning in Urban adaptation
Agent x Agent	Total degree Centrality	Those who are ranked high on this metrics have more connections to others in the same network.	Individuals or organizations who are 'in the know' are those who are linked to many others and so, by virtue of their position have access to the ideas, thoughts, beliefs of many others.
	Betweenness centrality	The betweenness centrality of node v in a network is defined as: across all node pairs that have a shortest path containing v, the percentage that pass through v.	Individuals or organizations that are potentially influential are positioned to broker connections between groups and to bring to bear the influence of one group on another or serve as a gatekeeper between groups.
Agent x Knowledge	Most knowledge	Assess the number of links between a certain agent and the different pieces of knowledge in the network.	An agent with a high value of most knowledge has access to a great variety of knowledge to be used in case of disaster.
Agent x Task	Most task	Assess the number of links between a certain agent and the different task that need to be carried out.	An agent with a high degree of most task plays a crucial role in the network due to her/his capability in performing different tasks.
Knowledge x Knowledge	Total degree of centrality	It calculates the importance of a certain piece of information according to the number of connected links.	The most central pieces of knowledge are those whose availability is crucial to make the other pieces of knowledge accessible.
	Betweennes centrality	The Betweenness Centrality of node v in a network is defined as: across all node pairs that have a shortest path containing v, the percentage that pass through v.	The betweennes centrality measure allows us to identify the information that could facilitate the process of information sharing.
Knowledge x Task	Most task	Assess the number of links between a certain piece of knowledge and the different task that need to be carried out.	The pieces of knowledge with a high value for this measure are fundamental for the effectiveness of the network, since without them a high number of tasks will be not carried out.
Task x Task	Total degree of centrality	It analyses the complexity of the connections within the task X task network.	Tasks with high degree of centrality are those that have to be carried out in order to allow the executions of the other tasks.

Table 2 Graph theory measures for detecting the most central elements in the interaction network

Different measures are mentioned in the scientific literature for the assessment of the network vulnerability, that is, those elements that could lead to failures of the network, lower performance, reduced adaptability, reduced information gathering, etc. (e.g. Carley, 2005). In this work, the elements of vulnerability are those that can represent a barrier to the information sharing.

The results of the SNA were, then, used to design CS for enabling collective urban planning for CC adaptation. The following section describes the results for the Helsinki case study.

3. Results

3.1. The Helsinki case study

In 2012 the Helsinki Region Environmental Services Authority (HSY) published a climate change adaptation strategy for the entire Helsinki metropolitan area. The strategy was prepared in close cooperation with the region's cities, regional authorities and other regional actors. The strategy was backed up by studies on regional climate and sea level scenarios, modelling of river flood risks and a survey of climate change impacts in the area. The strategy concentrates on the adaptation of the built and urban environment to the changing climate. The city of Helsinki has also been active in developing its climate change adaptation guidelines and measures, which are based on the adaptation vision, describing what a climate-proof Helsinki will look like in 2050. The vision 2050 states that "Helsinki is a climate-proof and safe city. Helsinki has adapted to the changing climate well in advance, and is prepared for extreme weather events and global impacts of climate change. Helsinki has integrated climate change adaptation into city planning and is continuously developing its adaptation activities. Economically most advantageous measures in the long run are evaluated. The city promotes adaptation business opportunities by providing an environment where it is easy to experiment and implement solutions that promote adaptation. Helsinki is known as an international leader in adaptation". Adaptation related plans and programs throughout the years have been: i) Storm water strategy 2007; ii) Flood strategy 2008; iii) Guidelines for maintenance of forests and green areas 2009; iv) Helsinki metropolitan area adaptation strategy 2012; v) Contingency plans to secure the energy supply system 2010; vi) Action plan for a sudden deterioration of air quality in the Helsinki Metropolitan Area 2010; vii) Survey of adaptation measures in building and maintaining public spaces 2010; viii) Green roof strategy 2016. In 2017, Helsinki adopted so called adaptation guidelines, which act as the official strategy document of the city in guiding adaptation. Nevertheless, the effectiveness of these measures is negatively affected by the lack of cooperation among the different institutional actors.

3.2. Ambiguity analysis for CS co-design

A round of semi-structured interviews was carried out, aiming at collecting the individual perception of the main climate-related risk in the local area, the potential impacts – both direct and indirect – the adaptation strategies and, finally, the potential role of climate services. The interviewees were also required to provide information about the flow of climate-related information among the different institutional and non-institutional actors. The latter data were used for the social network analysis.

Following the FCM methodology, the results of the interviews were analyzed in order to identify the keywords in the stakeholders' argumentation, and to define the perceived cause-effects links connecting the different keywords (variables) and their strength. FCM were developed for each of the interviewed actors.

The figure 3 (a and b) shows two examples of the FCM developed using the Helsinki interviews.

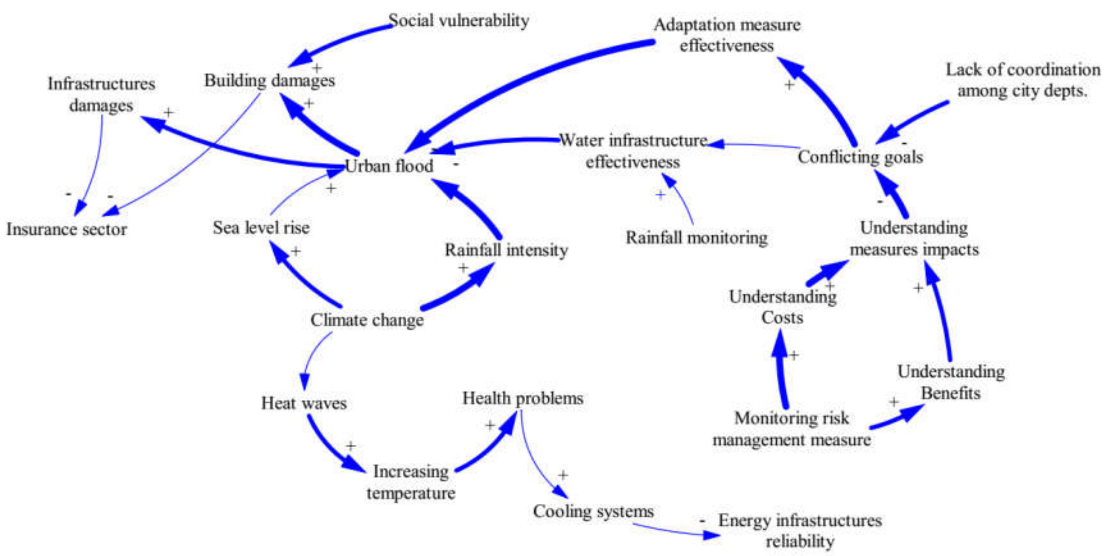

Figure 3(a): FCM representing the Helsinki Environmental Centre problem understanding.

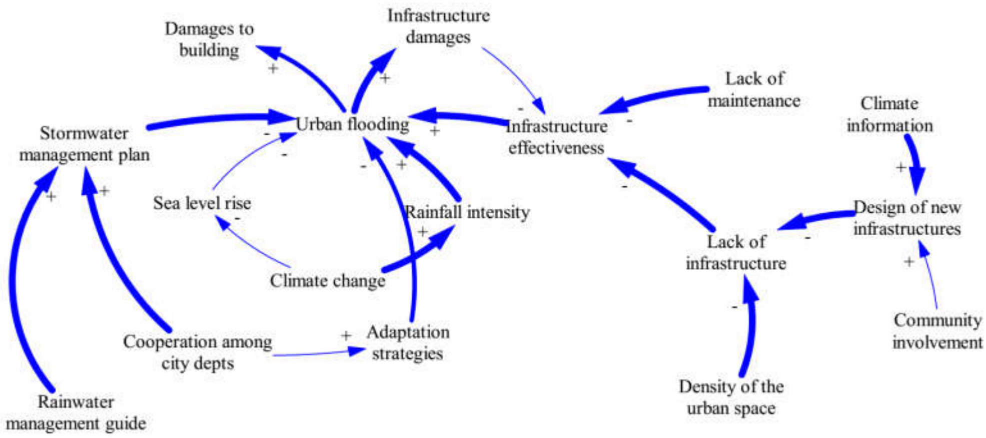

Figure 3(b): FCM representing the Public Work Dept. – Design office problem understanding.

The centrality degree measure was implemented in order to identify the key elements in the stakeholders' problem understanding. The following table summarizes the results of the centrality analysis for the interviewed stakeholders. It is worth mentioning that the results refer to the actors' perception.

Decision actor	Type of variable	Variable	Centrality degree (value)	Centrality degree (index)
Building control Dept.	Main effects	Urban flooding	2,00	High
		Increasing temperature	1,73	Medium
	Primary impacts	Storm water	5,53	Very high
		Heat island	1,31	Medium
	Secondary impacts	Building damages	3,63	High
		Energy consumption	1,70	Medium
		Building costs	0,61	Low
City Executive Office	Main effects	Urban flooding	1,00	Medium
	Primary impacts	Storm water	5,48	Very high
	Secondary impacts	Infrastructure effectiveness	1,92	Medium
Urban Planning consultancy	Main effects	Coastal flooding	3,28	High
		Sea level rise	2,00	High
	Primary impacts	Storm water	3,75	High
	Secondary impacts	Tourisms	0,78	Low
		Migration	0,75	Low
Helsinki Environ. Centre	Main effects	Urban flooding	5,68	Very high
		Increasing temperature	1,78	Medium
	Primary impacts	Storm water	1,64	Medium
		Heat island	2,28	High
	Secondary impacts	Economic development	2.42	High
		Building sectors	1.75	Medium
		Social vulnerability	1.69	Medium
		Urban infrastructures	1.67	Medium
Public Work Dept.	Main effects	Urban flooding	2,67	High
		Sea level rise	1,03	Medium
		Increasing temperature	0,75	Low
	Primary impacts	Storm water	1,78	Medium
		Heat waves	1,33	Medium
	Secondary impacts	Infrastructure effectiveness	0,97	Low
		Building damages	0,69	Low

Table 3 Main elements in the stakeholders' problem understanding (centrality degree)

These elements were used to support the elicitation of the information needs for each of the involved decision-actors. To this aim, the capability of the FCM to simulate qualitative scenarios were used. In order to elicit the decision-actors' information needs, the impacts of climate-related information on the effectiveness of the risk management actions were calculated.

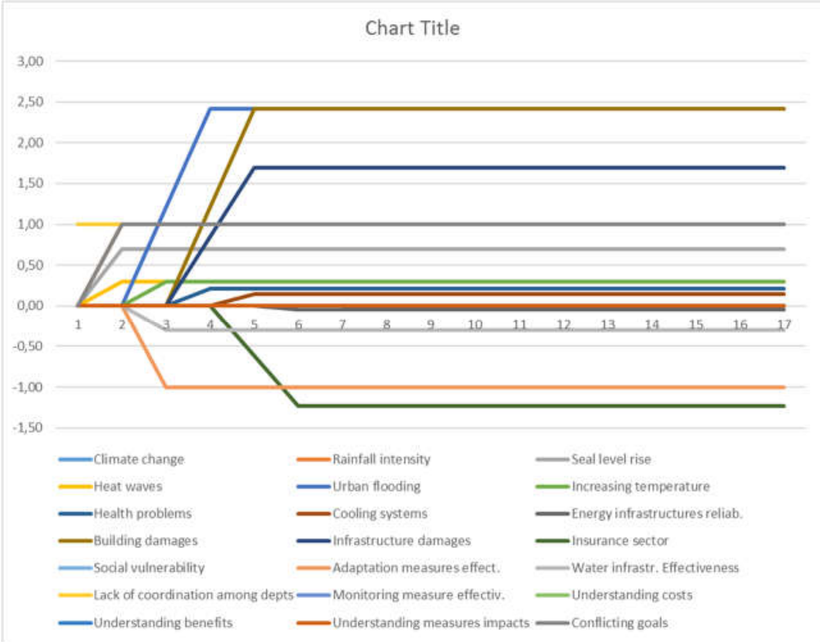

Figure 4(a): Values of the FCM variables in "no-information" scenario for the Helsinki Environmental Centre.

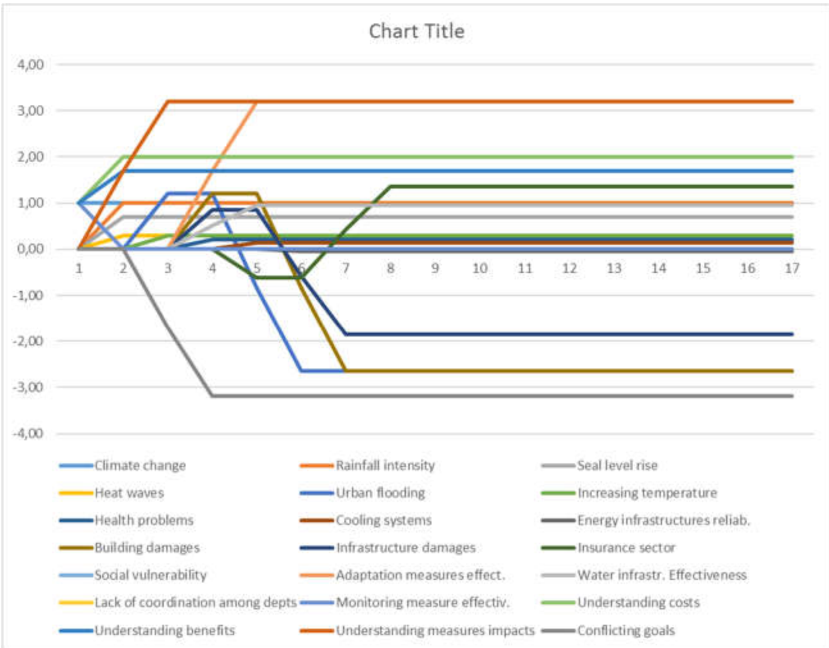

Figure 4(b): Values of the FCM variables in "available information" scenario for the Helsinki Environmental Centre.

The comparison between the two graphs allowed us to assess the impacts of the availability of the climate-related information. According to the Helsinki Environmental Centre problem understanding, the availability of the following information – "Monitoring adaptation measures effects"; "understanding costs/benefits" – allows to drastically reduce the probability of having conflicting goals among the different city departments. Consequently, the increased effectiveness of adaptation measures provoked a reduction of the urban flood intensity (primary impact), and the damages to buildings and infrastructures (secondary impacts). The following table shows the impacts of the two above mentioned information on the Helsinki Environmental Centre FCM central elements.

		Information availability impacts	
Main element	**Centrality degree**	**Monitoring the measure effect**	**Understanding cost/benefits**
Urban flooding	Very high	Positive	Highly positive
Increasing temperature	Medium	No change	No change
Storm water	Medium	Positive	Highly positive
Heat island	High	No change	No change
Economi developm.	High	Weakly positive	Weakly positive
Building sectors	Medium	Weakly positive	Positive
Social vulnerability	Medium	No change	Weakly positive
Urban infrastructures	Medium	Weakly positive	Highly positive

Table 4 Information availability impacts assessment according to the Environmental Centre FCM

Different information availability scenarios were simulated accounting for the stakeholders' individual FCM. The results were, hence, used to elicit the information needs for each of the involved decision-makers.

3.3. Social Network Analysis for climate change adaptation

The framework for the stakeholders' interviews was meant to collect individual experiences concerning the interactions, both formal and informal, activated during urban planning processes for climate change adaptation. Using the results of the interviews, the following maps were developed.

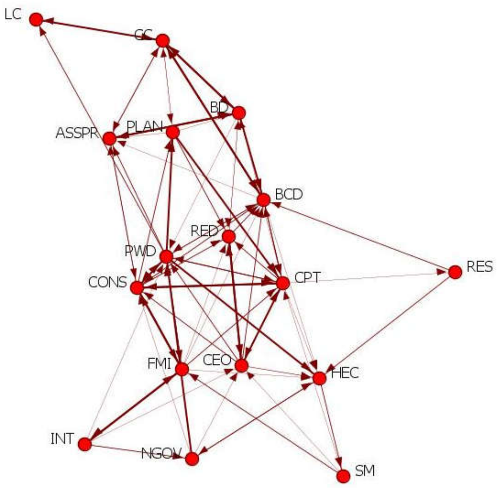

Figure 6 Map of the Agent x Agent interactions taking place during urban planning for adaptation. The thickness of the links represents the degree of importance according to the stakeholders' opinion.

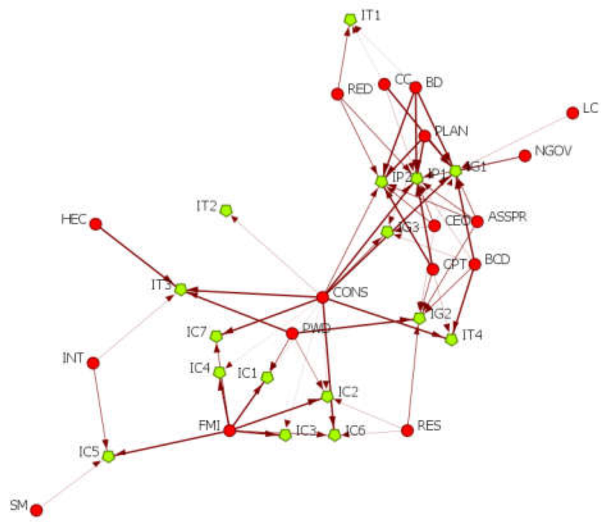

Figure7 Agent x Knowledge map.

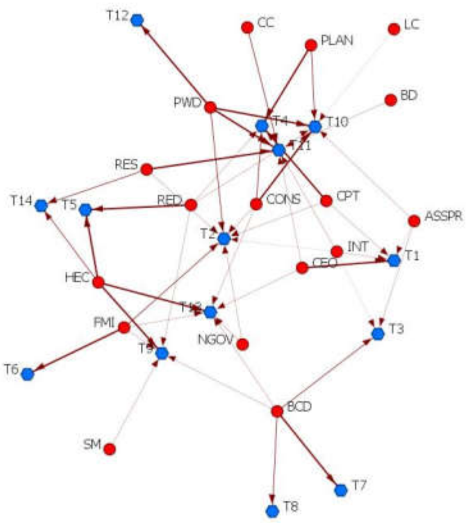

Figure 8 Agent x Tasks map.

The analysis of the different maps of interactions allowed us to identify the key elements in the collective decision-making process for urban adaptation.

Entity	Measure	Nodes
Agent	Total degree of centrality	PWD – Public Work Dept. CPT – City Planning Dept. BCD – Building Control Dept.
	Betweeness centrality	PWD – Public Work Dept. BCD – Building Control Dept. CPT – City Planning Dept. BD – Building designer
	Most knowledge	CONS - Consultancy agencies RES – Public research centres (FMI & SYKE)
	Most Task	BCD – Building control dept RES – Public research centres (FMI & SYKE) PWD – Public Work Dept.
Knowledge	Total centrality degree	IG2 – Storm water management requirements IG1 – Construction requirements IT3 – Green solution benefits ass. IP1 – Land use regulation
	Closeness centrality	IP1 – Land use regulations IG3 – Green adaptation guidelines IT3 – Green solution benefits ass.
	Most task	IG1 – Construction requirements IT3 – Green solution benefits ass IP1 – Land use regulation
Task	Total centrality degree	T2 – Storm water strategy development T3 – Construction guidelines T7 – Building activities control

Table 5 Key elements in the network of interactions according to the Graph Theory measures

The Graph Theory measures were also implemented in order to detect potential vulnerable point in the network. That is, those elements whose failure could provoke a failure or a reduction of the functionality of the entire network.

Type of elements	**Vulnerable elements**	**Meaning**
Agent	FMI – Finnish Meteorological Institute CONS - Consultancy agencies	These agents have a high specialization in knowledge but a low centrality degree
	PWD – Public Work Dept. BCD – Building control dept.	These actors have a high most task degree and a limited access to crucial information.
Knowledge	IT3 – Green solution benefits ass.	It has a high centrality degree but it is poorly shared.
Task	T2 –Storm water strategy development T3 – Construction guidelines T4 - Land use planning	These tasks are central in the process but have a very limited degree of sharing among the agents

Table 6 Elements affecting the vulnerability of the network.

4. Discussion

The results of the analysis described in the previous section were used to support the debate involving the different decision actors aiming at defining the main characteristics of a CS capable to support the collaborative planning for Helsinki urban adaptation to climate change. Specifically, two WS were organized in the case study. The first one aimed at guiding the stakeholders toward a satisfactory level of consensus over the most important information to be provided through the CS. The second WS was focused on using the climate-related information as a way to enable the collaborative planning for adaptation.

Concerning the first WS, three main phases were designed in order to facilitate the discussion among the stakeholders, i.e. the selection of the most suitable adaptation strategies, the usability of CS for supporting the selection and implementation of adaptation strategies, and the selection of the most suitable CS according to the participants' opinions. The results of the FCM analysis were then used to inform the debate. Firstly, participants were required to score the feasible adaptation measures. Individual inputs were collected and aggregated. The final ranking was discussed in the group.

	S1	S2	S3	S4	S5	S6	S7	Score
Building techniques	4,00	4,00	5,00	4,00	3,00	4,00	4,00	**4,00**
Green roofs	3,00	2,00	3,00	3,00	1,00	3,00	2,00	**2,43**
Green areas for stormwater retention	5,00	4,00	3,00	4,00	4,00	4,00	4,00	**4,00**
Grey infrastructures	3,00	3,00	3,00	4,00	4,00	4,00	4,00	**3,57**
Awareness raising	3,00	5,00	4,00	4,00	5,00	4,00	5,00	**4,29**
Stormwater management	5,00	5,00	3,00	4,00	4,00	5,00	5,00	**4,43**
Institutional cooperation	3,00	3,00	2,00	5,00	4,00	5,00	4,00	**3,71**
Urban density	1,00	2,00	3,00	4,00	4,00	5,00	3,00	**3,14**
Maintenance of green areas	4,00	1,00	3,00	3,00	4,00	4,00	4,00	**3,29**

Table 7 Ranking of the climate adaptation measures according to the participants to the first WS.

Participants were then required to describe how, according to their opinion, the climate-related information could facilitate the selection and implementation of the climate adaptation measures (Table 8). The discussion leaded the participants in defining a ranking of the available CS.

	Rainfall modelling	Rainfall monitoring	Construction requirements	Storm water management requirements	Urban zoning	Adaptation guidelines	Climate scenarios	Building costs	Adaptation measures benefit assessment	Adaptation measures cost assessment	Monitoring measure effects
Building techniques			X			X		X			
Green roofs	X	X	X	X		X	X	X	X	X	X
Green areas for stormwater retention					X	X	X		X	X	X
Grey infrastructures	X	X		X	X		X		X	X	X
Awareness raising			X	X		X	X	X	X	X	
Stormwater management	X			X	X	X	X		X	X	X
Institutional cooperation						X	X		X	X	X
Urban density					X	X	X				
Maintenance of green areas					X	X	X				

Table 8 Climate-related information – Adaptation measures connections according to the participants' opinions.

Table 8 allows to identify the most important climate-related information according to the stakeholders' problem understanding.

Concerning the second WS, a prototype of a platform for collaborative planning was tested in a controlled experiment. A real case concerning the design of a new urban area in the Helsinki outskirt was used as an example for simulating the sharing of information. Figure 9 shows the different phases of the collaborative planning tool.

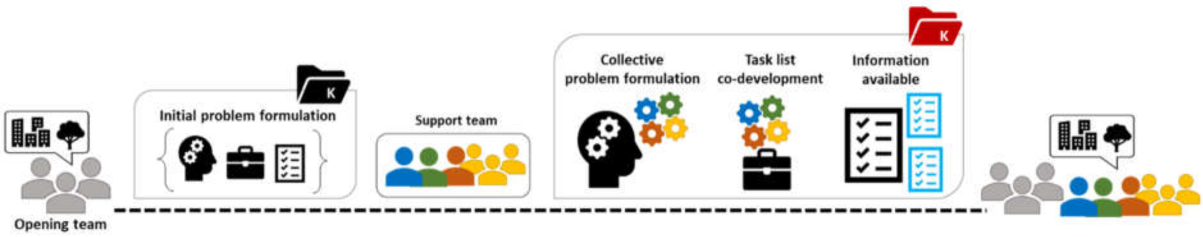

Figure 9 Collaborative planning tool based on climate-related information

The results of the previous activities were used to support the design of this WS. Specifically, the initial problem formulation and list of available information were based on the information needs elicitation. The creation of the supporting team and the task list co-developed were based on the SNA results.
The observation of the process and the participants' feedbacks collected at the end of the workshop allowed us to define the main characteristics of a web-based platform to enable the collaborative planning for climate change adaptation in Helsinki, as described in the following: i) The definition of the problem to be solved cooperatively need to be very specific. Generic issues could lead the participants toward endless discussion without the capability of achieving a solution. ii)The initial description of the problem, provided by the opening team to the supporting team, needs to be structured according to a framework that allow participants to easily retrieve information to be used during the debate. iii) The initial knowledge-base should contain exclusively information and data that need to be used to solve the specific problem at stage. Participants should have access to this knowledge-base well in advance. Finally, the way data and information are structured in the knowledge-base has to be clear and easily understandable for the participants. iv) The profiles of the participants need to be well structured and shared. Participant need to know who is participating in the discussion, what are the roles, the tasks and the objectives around the table. v) The involvement of the actors in the process has to account for the different phases of the planning process – i.e. from the strategy definition, to the actual action selection and implementation – and of the roles and responsibilities of the different actors. vi) The availability of an information dashboard, where all the participants can find out who-is-owning-what information is of utmost importance. This dashboard will allow participants to gather all the information needed for performing their tasks.

5. Concluding remarks

The activities described in this work allow to provide answer the two research questions:

- ambiguity in problem frames and differences in information needs are not necessarily a barrier to the collaborative planning. Making the stakeholders aware of these difference could enable the creative decision-making process leading to innovative adaptation solutions. Climate services design should be based on the full understanding of these differences.
- Climate services should be conceived as platform for the sharing of information and task. CS should be capable to emphasize the role of the central elements in the interaction network.

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