Climate Services 17 (2020) 100100

Contents lists available at ScienceDirect

Climate Services

journal homepage: www.elsevier.com/locate/cliser

Original research article

Urban adaptation to climate change: Climate services for supporting collaborative planning

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ARTICLE INFO

Keywords:
Urban planning for adaptation
Collaborative planning
Climate services
Ambiguity analysis
Social Network Analysis

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. Urban planning for adaptation is largely considered as a collective process. This raises the importance of the availability/usability of proper "planner/user friendly" interfaces to interpret and translate the available information into adaptation decisions, and to facilitate the information sharing and collaborative decision making within the interaction network in which the different actors are embedded. Nevertheless, collaborative planning is far from being the standard in urban adaptation. The activities carried out in EU-MACS aimed at detecting and analysing the main barriers hampering the process. To this aim, Problem Structuring Methods and Social Network Analysis were implemented. The evidences collected in an urban case study – i.e. Helsinki – demonstrated that ambiguity in problem understanding and information needs, and missing connections in the mechanisms of interaction among actors-resources-tasks could hamper the effectiveness of collaborative planning and create inefficient flow between information production and decision process. Starting from these premises, and referring to the results of an extensive literature review about existing tools, our research aimed at facilitating the use of climate services to enable the collective decision-making process.

1. Introduction

All over the world, cities are exposed to all kinds of stressors enhanced or even largely driven by climate change and climate variability. Moreover, more than half of the world population and the major part of the societies' assets and economic activities is located in urban areas (World Bank 2018). This makes cities both a contributor to climate change as well as a system particularly vulnerable to its impacts (Baklanov et al., 2018; Cortekar et al., 2016). Therefore, with an eye to UN sustainable development goals (https://sustainabledevelopment.un.org/) and with the aim to keep or make cities thriving, it is practically imperative for cities to develop adaptation strategies, controlling local climatic and biophysical conditions along with the risk of extreme events.

Mainstreaming climate strategies into existing policy processes is one of the most effective ways to address climate change in urban areas. To fulfill this aim, cities need advanced, tailor-made urban climate information that accounts for their particular physical and socio-economic characteristics, so as to assist urban planners and decision-makers in practices to design and implement urban adaptation measures that are cost-effective, justifiable and capable to address critical vulnerabilities (Doherty et al., 2016; Vincent et al., 2018). There has been a notable expansion in the supply and use of climate services (CS), which differ from climate information in that the former aim to provide decision-makers with *actionable* information to reduce climate-related risks and losses (Vincent et al., 2018).

Despite the clear growth in interest in climate services, the development and delivery of CS is often hampered by the lack of sufficiently meeting the users' needs and requirements (Cortekar et al., 2019; Tart et al., 2018; Perrels et al., 2018). The insufficient serving of user needs has several reasons, such as a too much science driven development of climate services and lack of competences or incentives to develop practical user oriented climate services, but also shortfalls at the user side, such as incomplete or even largely absent meaningful specification of information needs (Perrels et al., 2018). In the backgrounds counts also that the climate services market is still quite immature, meaning inter alia that value chains are often still underdeveloped. Consequently, public providers with strong roots in upstream climate services

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https://doi.org/10.1016/j.cliser.2019.04.004
Received 10 September 2018; Received in revised form 22 February 2019; Accepted 30 April 2019
Available online 16 May 2019

reach out to downstream service provision without properly contemplated business models to do so (Cortekar et al., 2019; Pawelek and Jenull, 2018; Stegmaier et al., 2019). Cortekar et al. (this issue) shows that public users of climate services tend to use public providers. This also applies to cities, even though the balance seems to be gradually changing in favour of private providers. Practically all of the aforementioned sources also emphasize that several types of collaborative models will be conducive for the development and provision of climate services better grounded on use-context relevance, as compared to conventional delivery models.

From the above sketch of challenges regarding matching climate services with user needs can be inferred that – at least in the current stage of climate services market development – more intensive interaction between provider and user is indispensable for adequate provision of fitting climate services. The actual involvement of stakeholders in co-producing CS appears to be still quite a challenge, and approaches for co-producing CS are as yet not well established (Klenk et al., 2015; Vincent et al., 2018). In many cases it will be necessary to co-design or at least jointly tailor a climate service, whereas, possibly, also the regular climate service provision is realized as a collaborative effort. Both the improvement of the fit and the collaborative structure are highly dependent on a proper understanding of needs, feasibility, affordability, and roles. This article deals especially with methods to better map and agree on service needs, also in conjunction with what the involved actors regard as feasible from the point of view of (1) data quality, (2) integration into existing information and decision cycles of the user(s), and (3) capabilities of the user organization. Roles and affordability are not so much discussed here as these aspects are in the first place guided by market conditions and regulations, as well as by organization and resourcing models. Admittedly there is a link between feasibility and affordability. The articles in this issue by Larosa and Mysiak, and by Perrels et al. do discuss some aspects of roles and affordability in connection with business models and market conditions.

In essence the article discusses the following questions:

1. To what extent are CS information needs within the urban planning domain irreconcilably different and to what extent would such genuine difference slow down development and uptake of climate services in cities?
2. What is the most suitable organizational model for the provision of climate service to and in the city, when multi-actor collaborative structures prevail?

Section 2 briefly introduces the state of the art in the analysis of actors and the information exchange between them, with emphasis on the selected approaches. Section 3 describes the integration between the two main methods used. Section 4 shows the results obtained in the Helsinki case study. Section 5 and 6 are meant to assess to what extend the work done allowed use to answer the main research questions.

2. Understanding actor networks and information networks for urban CS

The understanding of actor networks and information networks is relevant both for providers and users of CS. For CS providers such understanding helps to (further) develop a climate service into a sufficiently generalizable knowledge service-product relevant for different types of cities, where differences refer not only to physical but also to organisational and cultural differences. For CS users, i.e. the involved municipal and regional departments, and possibly also other non-municipal private and public actors, the analysis of actor and information networks helps to arrive at a balanced set of CS, customized to best possible relevance for the local context. More complex governance structures for the urban region can be an extra obstacle for arriving at converging views on the necessary set of climate services, but even if responsibilities are clear and structures not overly complex diverging views on the preferred set of CS can easily arise.

Three types of related obstacles affect the specification of needed climate services. Firstly, the *different interests and assignments* represented by different municipal departments and non-municipal actors can entail different views on the purpose of CS, e.g. purely serving resilience or also broader notions of sustainable development. In conjunction with purpose, but also because of different customs and experiences, typical time frames for solving issues may be different. In other words this first obstacle relates to actors being concerned with different subsets of needs. A second type of obstacle concerns *differences in culture, capabilities, and incentives*. Approaches to solutions can be technocratic or deliberative or whatever, thereby creating different expectations on what and how information is exchanged. Furthermore, some actors may have more problems with entirely grasping the risks and the remedies. Obviously, compromises that entail strategic developments without tangible rewards for some actors, can reduce willingness to collaborate. In other words, the second obstacle links to perceived feasibility. Last but not least, the *number and diversity of actors* and the diversity in their own obligations and planning cycles (introducing time dependence of relevance) creates *process complexity* in the establishment of common CS.

Whereas the first and second obstacle refer in the first place to analysis of the actor network and to a lesser extent to the information network, the third obstacle (process complexity) refers in the first place to the functioning of the information network, in terms of connectedness, quality and efficiency.

In order to overcome these barriers and foster the actual implementation of a bottom-up approach for co-developing climate-services for urban planning, this work assumed an analytical approach. Specifically, ambiguity analysis was used to detect the main differences in problem understanding among the decision-makers involved in urban planning, and to investigate if and how ambiguity impacted the effectiveness of the urban planning for adaptation process. 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 settings, the presence of ambiguity may have different implications. On the one hand, a diversity in frames can offer opportunities for innovation and the development of creative solutions (Brugnach & 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., 2017a). In this work, ambiguity analysis was carried out by implementing Fuzzy Cognitive Mapping (FCM) approach. As described further in the text, FCM was used to elicit and structure, allowing the comparison among stakeholders' problem frames and decision-making models, with specific reference on the role of climate information.

Moreover, Social Network Analysis (SNA) was implemented in order to: i) unravel the complexity of the network of interactions (both formal and informal) taking place among the different decision-makers involved/interested in the urban planning process; ii) identify the key elements, that is, those actors that can facilitate the flow of climate-related information; and, iii) detect the main vulnerable elements, that is, the elements whose failure could create barriers hampering the collaborative process for climate service development.

3. Materials and methods

In order to provide answers to the two main research questions, a multi-steps methodology has been developed in this work: i) Fuzzy Cognitive Maps for information needs elicitation and ambiguity analysis; ii) Social Network Analysis for organizational network Risk Analysis; and iii) Collaborative planning design tool.

3.1. Fuzzy Cognitive Maps for information needs elicitation and ambiguity analysis

The implementation of the FCM in this work intends to assess to what extent divergences in problem framing could also lead to barriers hampering the CS co-design and, thus, negatively affect the CS role in urban planning for adaptation. To this aim, firstly 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 deal with climate change impacts at urban level) has been related to the problem framing. Secondly, we analyzed in which condition discordance over adaptation-related information may result in discordance over climate services.

FCM can be considered as a “mirror” of the causes and effects chains that are inside the mind of decision-makers (Montibeller et al., 2001; Kok et al., 2009). FCM comprise 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 concepts.

A round of individual semi-structured interviews was carried out in order to elicit and structure the different decision-makers' problem understanding. The first issue to be addressed concerned the selection of the actors 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 to widen the set of stakeholders to be involved. In the case of Helsinki should however be clarified that in practice notably the needs for Helsinki were assessed and not for the other main municipalities in the Helsinki metropolitan area. This was driven by the dominant representation from Helsinki city in the workshops.

The interviews allow to collect the decision-makers' 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 the interviews for the FCM development, a “means-ends” hierarchical 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 described by the involved stakeholders. The interviewees were, then, required to describe potential and/or existing strategies to facilitate the adaptation of the urban system to climate change. Finally, 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 (Fig. 1) .

The developed FCM were used to infer the decision-makers' information needs. 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 was used to assess the impacts of climate-related information availability on decision-makers' capability to take effective decisions. The assumption here was that climate-related information was important for the stakeholders if its availability allowed the stakeholders to effectively address the key issues in her/his problem understanding.

Concerning the first analysis, FCM centrality degree was assessed. 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. A fuzzy linguistic function was developed for translating the centrality degree in a linguistic assessment (Giordano et al., 2017b).

The second analysis was carried out by simulating FCM scenarios. Two different scenarios were simulated. The Business-As-Usual scenario (BAU) was simulated running a FCM process (Kok et al., 2009) with the initial state of the information-related variable set to 0 – i.e. no climate-related information was available. Then, in order to assess the impacts of information availability on the stakeholder's capability to take effective decisions, the value of the connected variable was set to 1 in the second scenario, 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 the information-related scenarios allowed to assess the importance of the climate-related information according to the stakeholders' problem understanding. The more positive are the changes in the most central variables' states, and the more important is the information for addressing climate adaptation measures. We assumed that the information with a high importance degree represented the stakeholders' information need.

The ambiguity analysis was, then, carried out in order to detect similarities and differences among stakeholders' information needs. Two main elements were accounted for in order to analyse the ambiguity in information need, i.e. the importance degree and the information's role in the stakeholder's problem frame. Concerning the first element, a pairwise comparison was carried out considering the importance degree for each kind of information. In order to assess the difference in the importance degree, the fuzzy semantic distance measure was implemented (Giordano et al., 2007). This distance allowed to measure the difference between the stakeholders' information needs by using their linguistic assessment. The pairwise comparison among the stakeholders' judgements allowed us to develop the distance matrix (table 1).

The ambiguity analysis was completed by comparing the role attributed by each stakeholder to the information. To this aim, the comparison between the two FCM scenarios was accounted for.

3.2. Social Network Analysis for 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 decision-makers interact each other in exchanging 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. SNA in climate change adaptation allows to analyse the structural patterns of relations in networks that influence the social processes (Borgatti, 2006). Social network mapping can support the identification and analysis of barriers to cooperation and collaboration that could hamper the CS co-design process (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

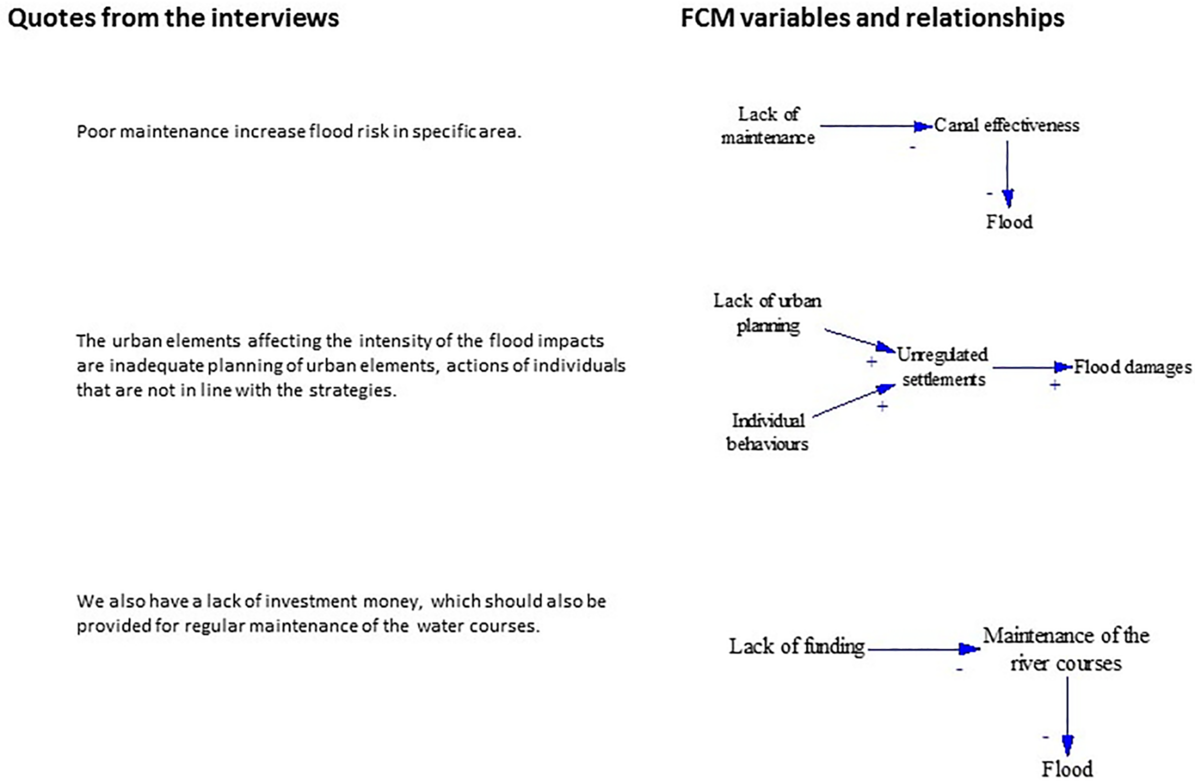

Fig. 1. Translating quotes from the stakeholders' interviews into variables and relationships of FCM.

Table 1
Distance matrix showing the differences in stakeholders' perception about the information I.

	A_1	A_2	A_n
A_1	–	D_{21}	D_{n1}
A_2	D_{12}	–	D_{n2}
A_n	D_{1n}	D_{2n}	–

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, 2004). 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, the whole set of actors involved in urban planning and climate-related risk management is considered as one heterogeneous organization (Giordano et al., 2017b). The interlocked networks is represented using the meta-matrix conceptual framework, as shown in the following table.

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 $A = V \vee \times \vee V \vee$. The links are also characterized by direction that indicates which agent mentioned the interaction.

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) (Table 3).

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 and to the collaborative planning.

3.3. The convergent thinking phase: the collaborative planning tool for urban adaptation

The convergent thinking phase aims to bring the different decision-makers in a collaborative planning process for achieving consensus over the climate-related information required to support the urban planning for adaptation. This is a key step for facilitating the co-design of CS for urban planning.

In order to facilitate the discussion among the involved decision-makers, the convergent thinking phase is organized in sequential steps referred to the collaborative planning process (Zaratè, 2013; Nogueira et al., 2017). The results of the information needs elicitation, the ambiguity analysis and the SNA are used to support the different phases.

The collaborative process starts when some member of the urban planning organization (i.e. the opening team) highlights the need to handle a certain problem related to urban adaptation. Afterwards, the opening team introduces the initial problem formulation, accounting for their own problem understanding. The FCM analysis is, then, used for better define the main issues that need to be addressed. As already stated, urban planning for adaptation is a collaborative process. Therefore, the second step concerns the definition of the support team, i.e. the group composed by other members of the organization that, due to their role, knowledge and responsibilities in the organization, need to be involved in the decision-making process for addressing the initial issue. The results of the SNA are used in this phase. Specifically, the support team is composed by: i) most central actors; ii) the actors that own important pieces of information; iii) the actors carrying out tasks useful for the process; iv) the actors that could represent a barrier to the process.

Table 2
Meta-matrix framework showing the connections among the key entities of social network (adapted from (Carley, 2005)).

	Agent	Knowledge	Tasks
Agent	*Social network:* map of the interactions among the different institutional actors in the different phases of the urban planning process	*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 process
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)

Once the support team has been defined, the participants of the planning process became aware of the different roles played by the other members (actors/tasks interaction in the SNA), and of the required and available information (actors/information interactions in the SNA and information needs). Moreover, participants became aware of the differences in information needs (results of the ambiguity analysis). Using these inputs, the support team and the opening team started discussing the task that need to be carried out in order to solve the problem at stage, and the information needed/missing for supporting the task performance. Considering the scope of the collaborative planning tool – i.e. facilitating the use and sharing of climate-related information – the process was considered concluded when a satisfactory level of consensus was achieved upon the most important information to be used for supporting the design and implementation of the most suitable solutions.

4. Results

4.1. 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 approved so called adaptation guidelines, which act as the official strategy document of the city in guiding adaptation. The effectiveness of these measures is to a varying extent negatively affected by shortfalls in deeper cooperation among the different institutional actors.

Even though for the realization of the various adaptation and resilience plans the different relevant departments have truly cooperated, some departments seem to 'own' (or appropriate) the problem more or allowing a wider scope than other ones. At least to some extent this has to do with the pertinence and scope of assignments of different

Table 3
Graph theory measures for detecting the most central elements in the interaction network.

Network	Network measure	Assessment	Meaning in DRR
Agent × 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 × 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 urban planning.
Agent × Task	Most task	Assess the number of links between a certain agent and the different task that need to be carried out in case of emergency	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 × 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 betweenness centrality measure allows us to identify the information that could facilitate the process of information sharing
Knowledge × Task	Most task	Assess the number of links between a certain piece of knowledge and the different task that need to be carried out in case of emergency	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 × 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

departments. Furthermore, it associates quite well with the difference between adaptation strategies or overview plans and more concrete adaptation implementation plans, entailing new phases with new actors (e.g. area or city block (re)developers) and is quite common for cities (cf. Bologna's experience: Giordano et al., 2018; Perrels et al., 2018). The choice for Helsinki as test case was made during the study's planning phase and relates to the relatively good (open) data availability and to the readiness of the municipal organisation to consider the use of climate services. Initially also a few representatives from other municipalities or private sector in the metropolitan area participated. Over time the focus gravitated to considering CS use by Helsinki city, even though links with intra-regional issues were not forgotten.

4.2. Information needs elicitation and ambiguity analysis

A round of semi-structured interviews was carried out, aiming to collect 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-related information. The interviewees were also asked to describe the way the different actors, institutional and non-institutional ones, interact with each other during the planning process. The information exchange process was specifically analysed. The latter data were used for the social network analysis (SNA).

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 Fig. 2 (a and b) shows two examples of the FCM developed using the Helsinki interviews.

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 (Table 4).

In order to facilitate the analysis, the variables in the stakeholders' FCM were clustered in three main sets, i.e. i) main effects, that is, the most relevant impacts due to climate changes in the urban area; ii) the primary impacts, that is, the direct effects of the main risks associate to climate changes; iii) secondary impacts, that is, the indirect impacts of the climate-related risks. Since most of the involved stakeholders were not familiar with FCM and graphical representation of cause-effects links, we decided to use the centrality degree to validate the developed FCM. Stakeholders were required to evaluate the reliability of the set of the most central issues. In most of the cases, the issues mentioned by the stakeholders coincided with those identified through the adopted approach. If changes were needed, participants were required to select the most central elements in the list of the list of the FCM variables. Changes were, hence, made in the stakeholder's FCM.

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. The basic assumption here was that an information could be considered important for a decision-actor if its availability positively affected the values of the main elements in the decision-actor's problem understanding. That is, if the information availability allowed the decision-makers to select and implement the most suitable actions for enhancing the climate-change adaptation of the urban system, and to reduce the expected primary and secondary impacts (Fig. 3).

According to the Helsinki Environmental Centre problem understanding, the availability of the following information – "Monitoring adaptation measures effects"; "understanding costs", "Understanding benefits" – allowed to drastically reduce the probability of having conflicting goals among the different city departments. This, in turn, will enhance the effectiveness of the planning process for adaption. Therefore, according to the stakeholder's understanding, this will lead to a more effective implementation of measures – e.g. water infrastructures – and to a reduction of the urban flood intensity (primary impact), and the damages to buildings and infrastructures (secondary impacts). Accounting for the stakeholders' FCM, the availability of the information did not have impacts on the other climate-related risks, i.e. the heat waves and high temperature. The comparison between the values of the central variables in the two scenarios allowed us the assess the importance degree of the for the above mentioned stakeholder.

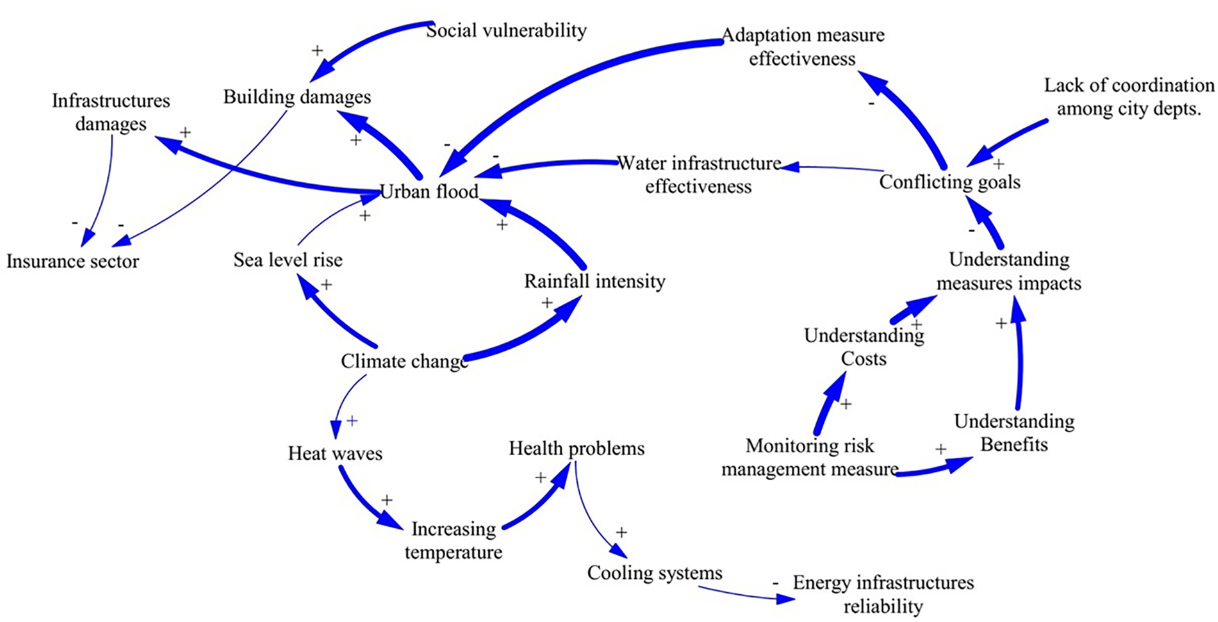

Fig. 2. (a): FCM representing the Helsinki Environmental Centre problem understanding. (b): FCM representing the Public Work Dept. – Design office problem understanding.

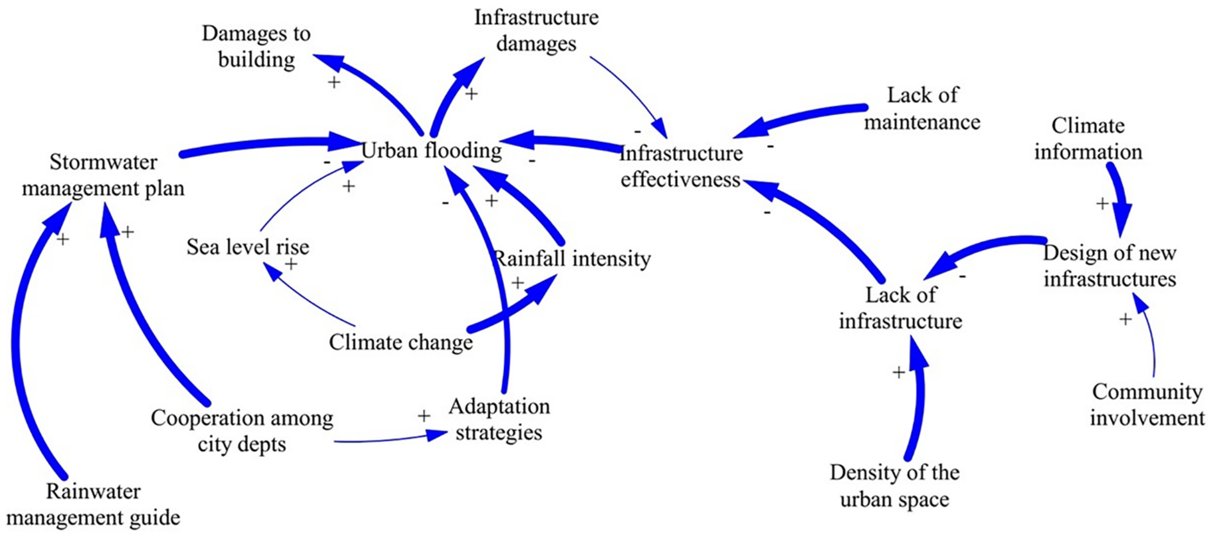

Fig. 2. (*continued*)

Different scenarios were simulated using the individual FCM. Table 5 shows the list of the available information, which was defined accounting for the information mentioned by the stakeholders during the interviews, either as an already used information or as a desirable one. It is worth mentioning that the analysis was not limited to the climate-related information. All the information required to support the urban planning for adaptation were accounted for in the analysis.

This list of information was then used to simulate different information scenarios, allowing us to assess the impacts of the information on the individual problem understanding, as described in the table 6.

The ambiguity analysis was, then, carried out by comparing the stakeholders' preferences concerning the suitability of the information related to climate change adaptation. Two kinds of analysis were carried out to this aim. Firstly, the semantic distance among importance degree assigned by each stakeholder to each information was assessed (Giordano et al., 2017b). This analysis allowed us to identify the most needed information – i.e. the information considered important by most of the stakeholders – and to create clusters of stakeholders with similar information needs – i.e. stakeholders that expressed similar importance degree for the same kind of information. The distance matrix was used to this aim (see Section 3.1).

Secondly, the roles of the information in the stakeholders' problem frames were compared. To this aim, the causal connections between the kinds of information and the most central issues were accounted for. This allowed us to describe the expected information impacts according to the stakeholder's problem understanding.

The ambiguity analysis showed that the most consensual

Table 4
Main elements in the stakeholders' problem understanding (centrality degree).

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

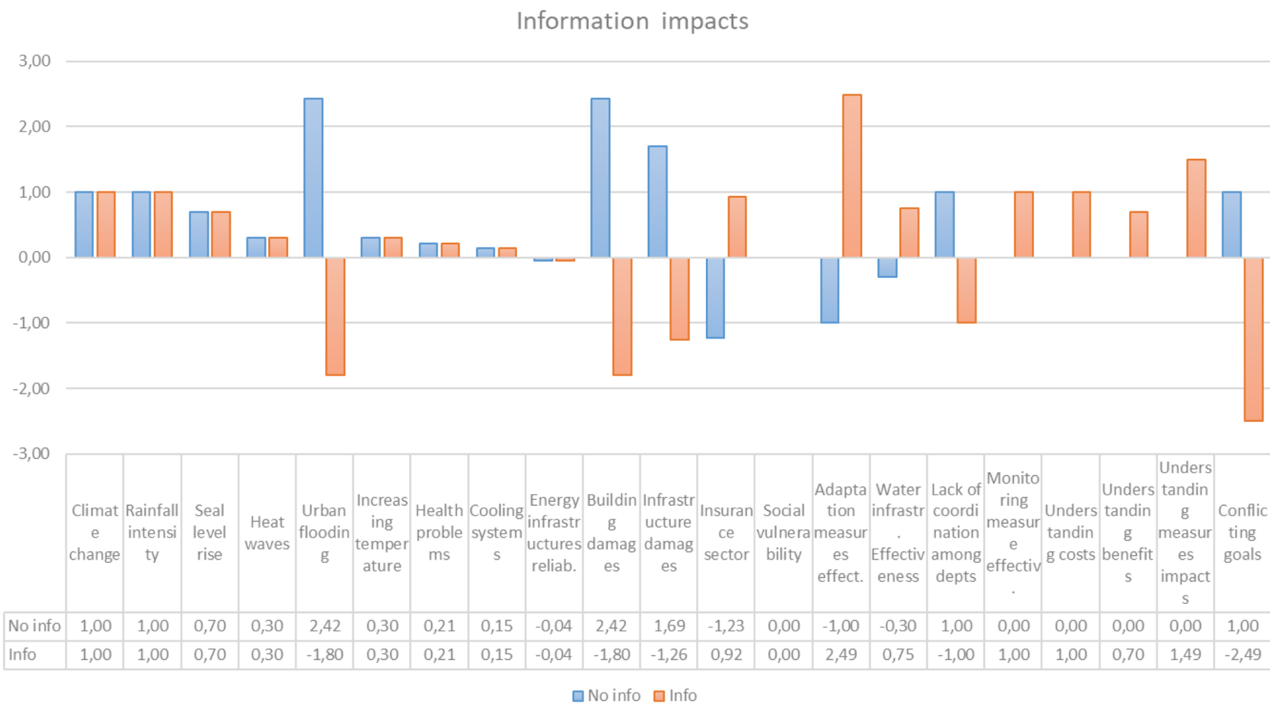

Fig. 3. The graph shows the state of the variables in the Helsinki Environmental Centre in two scenarios: without climate-related information and with information.

Table 5
Type of information for climate change adaptation. IP “planning information”; IC “climate-related information”; IG “guidelines information”; IT “technical information”.

Information	Acronym
Land use regulations	IP1
Rainfall modelling	IC1
Rainfall monitoring	IC2
Temperature data monitoring	IC3
Temperature modelling	IC4
Construction requirements	IG1
Storm water management requirements	IG2
Urban zoning	IP2
Green adaptation guidelines	IG3
Climate scenarios	IC5
Sea water level monitoring	IC6
Sea water level modelling	IC7
Building costs	IT1
Wind monitoring	IT2
Adaptation measures benefit assessment	IT3
Adaptation measures cost assessment	IT4
Green areas state assessment	IT5
Monitoring measure effects	IT6

information was the “adaptation measures cost/benefits assessment”. Most of the participants stated that the availability of this information would have a positive impact on the effectiveness of the collaborative planning process. It is also worth mentioning that technical information and guidelines were consensually considered as important.

The results of this ambiguity analysis were used for supporting the convergent thinking phase. Moreover, the analysis of the causal connections linking the information and the central elements in the stakeholders’ FCM allowed us to define the reasons why information is important for each stakeholder.

4.3. The social network analysis for the urban planning process

In order to analyse the way the different actors interact during a decision-making process for the implementation of adaptation measures, the SNA methodology previously described was implemented in the Helsinki case study. 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. The interviews allowed to define the set of actors involved in the interaction networks activated in the urban planning, and the set of tasks that need to be carried out (Tables 7–9).

Using the results of the stakeholders’ interviews, the Agent × Agent matrix was developed describing the strength of the interactions among actors, as perceived by the stakeholders. The methodology described in Giordano et al. (2017b) was implemented for eliciting the importance degree. The matrices were used as input for the development of the networks maps. The software ORA© was used to map the interactions. Fig. 4 shows the Agent × Agent network (a), and the Agent × Knowledge network (b).

Fig. 4(b) shows that there is no (or very limited) exclusivity in the agent-knowledge interactions. This means that every piece of knowledge is connected to different actors and that the actors are either owning the information or requiring it. In any case, the cooperation among the different actors is relevant to facilitate the flow of information and to enhance its effectiveness in supporting the urban planning for adaptation.

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

The graph theory measures were also implemented in order to detect potential vulnerable points in the network. That is, those elements whose failure could provoke a failure or a reduction of the functionality of the entire network. The two actors with high specialization in knowledge production and use, i.e. the Regional Environmental Service (RES) and the consultancy agencies have a quite low centrality degree and betweenness centrality. This strongly reduce their capability to enabling an effective information sharing process. This does not mean that these actors do not have and/or produce useful information for enabling the climate adaptation process. A lot of the produced information is public (and often belongs to open data platforms) or would be available under certain conditions. Nevertheless, most of the

Table 6
Elicitation of the information needs for the different stakeholders in the Helsinki case study. Each row describes the information scenario for each institutional actor.

	Land use regulations	Rainfall modelling	Rainfall monitoring	Temperature data monitoring	Temperature modelling	Construction requirements	Storm water management requirements	Urban zoning	Adaptation guidelines
City Executive Office	Medium	High	Medium	Low	Low	Low	Medium	Medium	High
FMI	Low	High	High	High	High	Low	Low	Low	Low
City Planning Dept.	High	Low	Low	Low	Low	Low	High	High	High
Public Work Dept.	Low	Medium	High	Low	Low	Low	High	Medium	Low
Real Estate Dept.	High	Low	Low	Low	Low	High	Medium	High	High
Building Control Dept.	Low	Low	Medium	Low	Low	High	Medium	Low	High
Helsinki Environm. Centre	Medium	Low	Low	Low	Low	Low	Medium	Medium	High
Private consultants	Low	High	High	Medium	Medium	Low	Low	Low	Low
Regional Environm. Service	High	Low	Medium	Medium	Low	Low	High	Low	High
Construction companies	Medium	Low	Low	Low	Low	High	Low	High	High
Building designer	Medium	Low	Low	Low	Low	High	Medium	High	High
Planning agency	High	Medium	Medium	Low	Low	Low	High	Medium	High
Social Media	Low	Low	Medium	Low	Low	Low	High	Low	Low
National Gov.	Low	Medium	Medium	Medium	Medium	Low	Medium	Low	Low
Practitioners association	High	Low	Low	Low	Low	High	High	High	High
Local community	Medium	Low	Low	Low	Low	High	Medium	Low	High
Int. Organizations	Low	High	Low	Low	High	Low	Low	Low	Medium

	Climate scenarios	Sea water level monitoring	Sea water level modelling	Building costs	Wind monitoring	Adaptation measures benefit assessment	Adaptation measures cost assessment	Green areas state assessment	Monitoring measure effects
City Executive Office	High	Low	Low	Low	Low	High	High	Low	Low
FMI	High	Medium	Medium	Low	Low	Low	Low	Low	Low
City Planning Dept.	Low	Low	Low	Low	Low	High	High	Medium	Medium
Public Work Dept.	Medium	Low	Low	Low	Low	High	High	High	Low
Real Estate Dept.	Medium	Medium	Medium	High	Low	Medium	High	Low	Low
Building Control Dept.	Low	Low	Low	Medium	High	High	High	Low	High
Helsinki Environm. Centre	Medium	Low	Low	Low	Low	High	High	High	High
Private consultants	High	Medium	Medium	High	Medium	Medium	Medium	Low	Low
Regional Environm. Service	High	Medium	Low	Low	Low	Low	Low	Low	Low
Construction companies	Low	Low	Low	High	Low	Medium	High	Low	Low
Building designer	Low	Low	Low	High	Low	Medium	Medium	Low	Medium
Planning agency	High	Low	Low	Low	Low	Medium	Medium	Low	Low
Social Media	High	Low	Low	Low	Low	High	High	Medium	Low
National Gov.	High	Medium	Medium	Medium	Low	Low	Low	Low	Low
Practitioners association	Medium	Low	Low	High	Low	Medium	Medium	Low	Low
Local community	Medium	Low	Low	High	Low	High	High	Medium	High
Int. Organizations	High	Low	High	Low	Medium	Low	Low	Low	Low

Table 7
List of actors involved in the urban planning network of interactions.

Actors	Acronym
City Executive Office	CEO
Climate-related research centres (FMI and SYKE)	RES
City Planning Dept.	CPT
Public Work Dept.	PWD
Real Estate Dept.	RED
Building Control Dept.	BCD
Helsinki Environmental Centre	HEC
Private consultants	CONS
Regional Environmental Service	RES
Construction companies	CC
Building designer	BD
Planning agency	PLAN
Social Media	SM
National Government (min. of Environment and min. of Finance)	NGOV
Practitioners association	ASSPR
Local community	LC
International Organizations	INT

Table 8
List of tasks to be implemented in urban planning for adaptation.

Tasks	Acronym
Public investments	T1
Storm water strategy	T2
Construction guidelines	T3
Land use planning	T4
Water quality assessment	T5
Climate modelling	T6
Building activities control	T7
Training activities	T8
Awareness raising	T9
Designing public spaces	T10
Infrastructures development	T11
Maintenance of public areas	T12
Adaptation advises	T13
Risk analysis	T14

interviewed actors were not aware of the availability of this information. The centrality and betweenness measures were implemented in this work to assess to which degree the available knowledge and information put these actors at the centre of the adaptation process. These measures show that efforts are required in order to enhance the usability of the available information.

For the same reasons, the RES could represent a vulnerable point in the network because it has a high most task degree, but a low level of centrality. It is worth mentioning that the centrality degree describes the capability of a specific actor to interact with the others and, thus, to share important information with them. The low degree of centrality of RES means that only few institutional actors are capable to use the scientific information for performing their tasks. It is worth mentioning that some actor could decide to shield the power in a municipal organization by keeping low the level of information sharing. These actors are characterized by a high most central degree and a quite low centrality degree in the Actor X Actor network. Furthermore, some of the actors with the most task degree have a limited access to crucial information. This could be due to their limited capability to comprehend and use the available scientific information. That is, they have a low most knowledge degree. Specifically, Public Work Dept. (PWD) and Building Control Dept. (BCD) have limited access to climate-related information. Concerning the knowledge, the Green solution benefits assessment seems to have an important role both for facilitating the implementation of tasks and for enabling the information sharing

Table 9
Key elements in the network of interactions according to the graph theory measures.

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

process. Concerning the tasks, the three most important ones, i.e. T4, T3, and T2, have a very limited degree of sharing among the agents. That is, although these tasks play a crucial role in the urban adaptation process, they seem to be poorly cooperative. This could represent a barrier to the effectiveness of the process.

4.4. Supporting the co-design of climate service for collaborative planning in Helsinki

The results of the two phases of the analysis were used to design and organized a stakeholder workshop in Helsinki. The main aim of the workshop was to test and evaluate the usability of the information from ambiguity analysis and SNA to support the collaborative process for designing climate services to be used in urban planning for adaptation. Different institutional actors were involved. Given a specific urban policy issue, the process allowed decision-makers to identify other actors that need to be involved to develop a consensual and effective solution to the problem at stage.

Stakeholders were involved in a group exercise aiming at developing a consensual solution to the following problem: how to design the most climate smart urban district in Helsinki? How to integrate the new urban area in the existing city structure? (Haaga, Pitäjänmäki). The "Vihdintien bulevardikaupunginosa" (Boulevard district of Vihdintie street) was introduced as case study.

In order to facilitate the discussion, participants were provided with a box containing initial information on the case. This box was named "initial knowledge-base", and it represented the initial set of available concepts on the issues to be addressed during the decision-making process. Participants were also provided with a folder containing all the basic information concerning their role in the decision process, i.e. main objectives, tasks to be performed, information owned and used. The results of the FCM and SNA were used to this aim. Specifically, we referred to the central elements in the stakeholders' FCM and to the Agent X Tasks matrix (SNA).

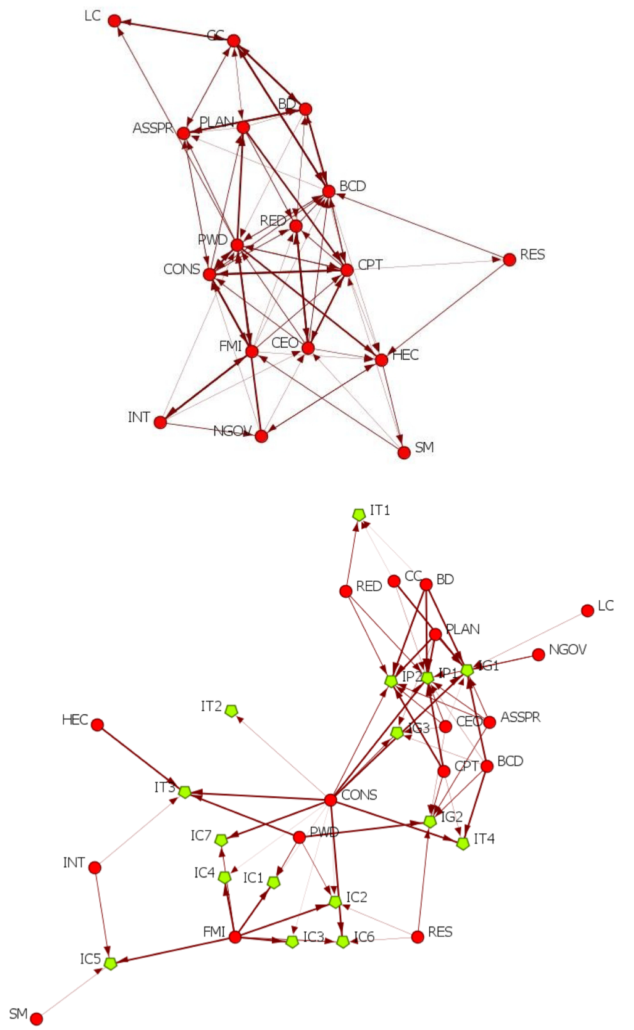

Fig. 4. a) Agent × Agent map of interactions; b) Agent × Knowledge map.

The workshop was structured in "time-boxed" interactions. Participants had a limited time slot for contributing to specific topics of the discussion. In order to simulate a real collective decision-making process, the following phases were identified:

- Initial and collective problem formulation: The opening team introduces the initial problem formulation, based on the case study area, and the specific objectives to be achieved (e.g. reducing flood risk, increasing the urban areas, reducing the energy consumption, etc.). Referring to the SNA, the actors having a role in achieving these objectives – i.e. through information sharing and/or task performance – were invited to take part in the process.
- Task list co-development: At this stage, the participants were required to define the list of tasks that needed to be carried in order to achieve the objectives defined in the previous step. The results of the SNA were used to facilitate this phase. Specifically, the Agent X Task matrix was used to define the list of tasks that, according to the information collected in the previous phases, had to be carried out. The opening team submitted the initial list of tasks (e.g. climate scenario modelling, risk analysis, transportation planning, public space design, etc.). The other participants were required to add and or challenge the initial list of tasks. The list was considered as completed when a consensus was achieved.
- Information to be used in the process: Participants were required to identify the most important information to be used for carrying out the tasks. To this aim, participants were provided with two information panels/boards: the first contained information available in the interaction network (results of the SNA), the second contains the supplementary information that can be gathered using available climate services (the results of the information needs elicitation phase were used to this aim). Participants were also provided with the list of actors owning the different pieces of information (results of the SNA – Agent X Information matrix). Finally, the results of the ambiguity analysis showing the differences in information needs among the participants were shared. During the workshop, participants used these lists to identify the other actors with whom they had to interact in order to gather the needed information, and the actors with whom they had to cooperate in order to enhance the effectiveness of the information. The interaction was simulated during the workshop.

The process ended when all participants considered the set of available information sufficient for carrying out the tasks needed to solve the problem at stage. It is interesting to notice that most of the participants agreed that, in order to be actually effective in urban planning, climate-related information needs to be integrated with other kinds of adaptation-related information, such as health conditions, traffic control and management, examples of best practices. Besides, participants agreed on the need to involve local communities in providing useful information for supporting the urban adaptation to climate change.

Feedbacks were collected from the participants at the end of the workshop, in order to assess the effectiveness of the proposed process. Most of the participants agreed that having a clear idea of the whole set of information available "around the table" positively affected the flow of information and, consequently, the effectiveness of the collaborative process. As stated by the participants, one of the main drawbacks hampering the collaboration among the different municipal departments involved in urban planning is the lack of awareness about the information actually available in the organization, and where – i.e. in which dept. – this information can be retrieved. The availability of the results concerning the information needs elicitation – i.e. ambiguity analysis – and the Agent X Information analysis (SNA), contributed to overcome these barriers and to enable the consensus achievement process over the most important climate-related information to be referred at during the planning process.

5. Discussion

The analysis of the results of the Helsinki case study allowed us to draw conclusions concerning the suitability of the proposed integrated approach for supporting the stakeholders' engagement in climate service design was assessed. This will facilitate the repeatability of the adopted methodology.

The activities carried out in this work corroborated the findings according to which bottom-up approaches, based on stakeholders and users' engagement in the co-design of CS, play a key role in enhancing the usability of CS. Nevertheless, we learned that in the domain of urban planning for adaptation, the stakeholders' engagement process is often hampered by the difficulties in the specification and identification of the information needs and requirements, which are shakier than one might think, even in cities that are climate aware and active, such as Helsinki. This is mainly due to the heterogeneity of the information needs, which is unavoidable in a complex decision-making environment, such as those related to urban planning for adaptation. Moreover, with respect to the information acquisition and use, most of the decision-makers involved in the process seemed to act as an isolated entity, accounting exclusively for their own information needs and ignoring those of the others (Perrels, 2018). This impedes the effective identification of the users' information needs and requirement, to be used as basis for the CS co-design process.

The activities carried out in the Helsinki case study within the EU

MACS project framework demonstrated that the effective engagement of stakeholders in the CS co-design process requires a deep understanding of the main differences in information needs and requirements. This does not imply necessarily to reach a full consensus over the climate-related information. As stated previously, differences are unavoidable due to the different institutional roles and tasks in a municipal organization. Nevertheless, the work done during the workshop demonstrated that, working through the differences, participants arrived to a mutually acceptable solution. Making the differences in information needs and requirements explicit is a key step for enabling the dialogue that leaded to a process of mutual understanding that is needed for creating a shared and connected frame. The FCM approach and the results of the ambiguity analysis contributed to this scope by making clear where stakeholders' frames differed each other and how these differences affected the information needs. Besides, it is worth to mention that the validation of the FCM showed that the approach adopted for structuring the FCM from the results of the interviews was suitable for representing graphically the stakeholders' problem understanding.

In co-creation processes, the decision-makers' willingness to work together depends on their expectations regarding the benefits of cooperation and its outcomes, even if they have different approaches to solve the same problem. This requires that the parties recognize that they are needed and they need others for developing (more) effective solutions (Brugnach & Ingram, 2010). The implementation of the SNA contributed to make the participants aware of how strongly intertwined their activities are in the urban planning process for climate adaptation. The map of interactions graphically showed to dense web of interaction among three key elements in the process, i.e. actors, information and tasks. The high level of collaboration that is required in urban planning became evident to the stakeholders. Specifically, the agent-task and the information-task maps were considered important by the participants in order to enable the collaborative planning. Most of the participants to the workshop were only partially aware of the actual role played by the others in the process. Participants became also aware of the information that need to be shared in order to facilitate the collaborative planning, and of the actors that could facilitate the process due to their access to key resources. The detection of the central elements and vulnerable elements in the network of interactions could allow to introduce innovation in the interaction mechanisms among actors/information/tasks. e.g. in the Helsinki case, efforts were carried out to involve the Public Work Department (PWD) in the process. Due to its centrality in the agent network, it could facilitate the collaborative process. Nevertheless, due to its limited access to climate-related information, it could also represent a barrier hampering the process. Therefore, the PWD information needs were highlighted in the process for defining the set of information to be used. Besides, considering the high degree of centrality, the guidelines for improving the construction activities and for designing adaptation measures were included in the initial knowledge-base available for all participants.

Please note that we discuss only the methods that help to detect differences among actors and sources of these differences. No solutions for improving some underlying conditions have been tested, except for the effect of adding or better sharing information. For example, we do know that better explanation of achievable benefits, especially if supported by peer experiences, is a strong motivator for starting to use CS (Damm et al., 2018; Hamaker-Taylor et al., 2018), and hence may also help to achieve compromises within a user group.

The analysis of the process allowed us to identify the main limits of the adopted approaches. Firstly, the comparison between the adopted approach and the other methods for supporting the collaborative decision-making process – i.e. focus groups, participatory modelling, etc. – highlights the amount of time required to carry out the whole process, starting from the individual interviews, modelling the individual decision-models and detecting the main differences. Nevertheless, the results showed that making the participants aware of the existing differences greatly facilitate the discussion. Therefore, we can state that the time consuming first part of the process – i.e. the divergent thinking phase and the analysis of risk perception – allowed a fast and effective convergent thinking phase. From the point of view of better facilitating the uptake of climate services by cities one may wonder whether a simple tool could be devised for this, to be used inside the municipality – probably recurrently – during adaptation planning cycles. Over time the involved departments will develop a sort of improved awareness of this informational landscape.

Secondly, the adopted method claims for the long term engagement of the stakeholders. Since the divergent thinking phase is based on the elicitation and analysis of the individual problem frames, having the same stakeholders participating in all the different phases is a key for the success of the whole process. To this aim, efforts were carried out since the early phases of the method implementation in order to meet the actual needs and concerns of the different stakeholders. The results of the individual FCM analysis concerning the main goals to be achieved were used to enhance the communication between the analysts and the participants in the whole process. This could increase the stakeholders' willingness to take part in the different phases of the process. Finally, the selection of the stakeholders to be involved in the process had a great impact on the effectiveness of the different phases. Non-ideal coverage of both institutional and non-institutional actors can be avoided by integrating the results of the SNA in the selection of the stakeholders. Specifically, the identification of the most central actors should allow to get the commitment from important actors in the organization. This could have a positive impact on the level of stakeholders' engagement in the process. That is, as the social map was developing, the most central actors were added to the list of the participants in the different phases of the process.

6. Concluding remarks

The role of stakeholders' engagement in CS co-design has been largely emphasized in previous works as a way for enhancing the usability of CS. The information users, the information needed and how this information is integrated in the urban planning process should be at the core of the CS design and implementation. The results of the activities described in this work demonstrated that the CS co-design process for the urban planning for adaptation is still hampered by two main barriers. That is, the existence of multiple, and often conflictual, information needs and requirements in complex organizations such as a municipality; and the lack of understanding of the complex network of interactions taking place among the broad set of actors involved in the urban planning process. Neglecting these barriers could lead the decision-makers to act as isolated agents when dealing with the selection and acquisition of information for climate-change adaptation processes. This, in turn, could negatively affect the uptake of CS in urban planning.

The activities carried out in the Helsinki case study demonstrated that efforts are needed in order to enable cooperation among the different departments within the municipality, and beyond the organization borders, involving other public institutions and private actors as well. This work demonstrated that the integration of analytical approaches such as Fuzzy Cognitive Mapping, Ambiguity analysis and Social Network Analysis could facilitate overcoming the barriers and enabling the collaborative process for CS design and acquisition. The work done in Helsinki allowed us to affirm that, in order to transform ambiguity from a barrier to an enabling factor for the CS collaborative design the key is to make it explicit. Decision-makers need to know if and where their problem frames differ each other, how these differences affect the process of information acquisition and interpretation, and what is the information role in the individual actor's decision-making process. The availability of these results facilitated the debate among the different stakeholders.

Finally, the work done in Helsinki demonstrated that effective stakeholders' engagement process in CS co-design claims for effective interaction mechanisms involving actors, information and tasks in urban planning for adaptation. The implementation of the SNA allowed to detect the key nodes of intervention in the network, that is, the elements that, due to their position in the network, can greatly influence the effectiveness of the collaborative process.

Nevertheless, we need to reiterate that the presented approaches are important for more effectively assessing and specifying the needs for CS and to understand the approximate feasibility boundaries, as these are prerequisites for useful CS, but not sufficient. When conducting these analyses, it should be checked that how stable the regulatory and organizational context of both the user(s) and provider(s) are. On the other hand, the mapping of actors' positions and of information interaction may also produce insights that could hint at the relevance of new organizational alternatives (new business models for CS) or needs for reconsiderations of some regulations (responsibilities, public/private domain delineations, etc.). These aspects are as such outside the scope of this article and the underlying segments of the EU-MACS project.

Acknowledgement

The research activities described in this work have been financially supported by the EU-MACS Project (Project ref. 730500) within the H2020. We would like to thank the project team for many stimulating discussions and kind cooperation. Moreover, a great thanks goes to the institutional and non-institutional stakeholders that provided their knowledge and expertise at the base of this work.

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