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Defining the roadmap towards city resilience

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ABSTRACT

A growing majority of the world's population lives in cities, and the concentration of people and critical services in cities increases their exposure to acute shocks and long-term stresses. Therefore, building resilient cities that are able to resist and absorb threats and are capable of adapting to and recovering from shocks and stresses is vital for the wellbeing of society. Although the literature offers several studies on how city resilience can be improved, operationalizing resilience is still a challenge. This article describes the different phases of the co-creation process followed in the development of a maturity model that can guide cities in assessing and future improving their resilience level. This co-creation process was conducted using different methodologies involving an interdisciplinary group of international experts who contributed their knowledge and experience to the development process of the maturity model. The outcome of this process is the final version of a maturity model that operationalizes the steps that should be taken to build city resilience.

1. Introduction

The world is experiencing the largest wave of urban growth in history. Over half of the world's population is now living in cities and according to the United Nations estimates, by 2050, 66% of the total world's population is expected to be urban (UN, 2014). With this rapid urbanization, cities are facing a variety of acute shocks derived from natural disasters and long-term stresses, such as the effects of climate change (Harrison and Williams, 2016; UNISDR, 2015a). Therefore, there is a need for cities to implement policies for increasing resilience and improving preparedness to cope with both acute shocks and long-term stresses (Spaans and Waterhout, 2017).

The concept of resilience has been applied in many different disciplines such as climate change, disaster risk reduction, and planning (Peng et al., 2017). This research considers resilience as a transversal capacity to deal with all kind of threats, expected and unexpected. Resilience goes beyond traditional risk management approach and it does not only take into account the type of threats towards the city is already preparing for but it is also focused on developing preventive and adaptive capacities to deal with any kind of unexpected threats (Park et al., 2013; Risk and Resilience Research Group – Center for Security Studies, 2011).

Making cities resilient to shocks and stresses in order to ensure the welfare of society has become a major concern for academics, emergency management practitioners and governments (Chmutina et al., 2016). Within the scope of this article, city resilience is defined as "*the ability of a city or urban region to resist, absorb, adapt to and recover from acute shocks and chronic stresses to keep critical services functioning, and to monitor and learn from on-going processes through city and cross-regional collaboration, to increase adaptive abilities and strengthen preparedness by anticipating and appropriately responding to future challenges*" (Smart Mature Resilience, 2016a, pp. 8). Due to the complexity and wide scope of the concept of resilience, operationalizing the city resilience-building process is still a challenge (Meerow et al., 2016), and governments and practitioners need support and guidance in order to be able to build resilience in the most optimum and effective manner (Weichselgartner and Kelman, 2014).

Defining the optimum path that cities need to follow in the resilience-building process enables cities to prioritize available resources and efforts. Within the Smart Mature Resilience (SMR) project, funded by the European Commission's Horizon 2020 program, a Smart Mature Resilience Maturity Model (SMR MM) that cities can use as a roadmap for effectively assessing and improving their resilience level has been developed. The SMR MM defines a sequence of stages for cities that enable to self-assess their resilience level and it includes resilience-building policies that cities should implement in order to improve their overall resilience level by moving forward from one stage to the next. Increasing the resilience level allows cities to address current emerging challenges such as climate change, social dynamics and critical infrastructure interdependencies. The tool has been developed for the decision makers at the city level responsible for building city resilience. The SMR MM was created through a process of co-creation since experts

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with different backgrounds and from different disciplines were involved in its development to ensure the usefulness and reliability of the resulting model. This co-creation process was conducted through different research methodologies that integrate the knowledge embedded in the experts' minds.

As a result of the co-creation process, five sequential maturity stages (Starting, Moderate, Advanced, Robust and Vertebrate) were defined. Furthermore, the policies that should be implemented at each stage in order to move to a more advanced maturity stage with an effective use of resources were described. These policies were classified according to four resilience dimensions (leadership and governance, preparedness, infrastructures and resources, and cooperation) that were identified from a literature review in field of the city resilience.

This paper aims to describe the activities carried out in this co-creation process, present the results obtained in each phase, show how these results provided input for the development of the SMR MM, and lay out the final version of the SMR MM. The paper is structured as follows: Section 2 explains the state of the art on city resilience frameworks and city resilience dimensions, and it explains the research contribution of this paper. Section 3 describes the methodology followed in the co-creation process and Section 4 presents the results obtained from the different phases within the co-creation process. Section 5 illustrates the final version of the SMR MM and lastly Section 6 states the main conclusions of this research and the future research lines.

2. State of the art

A city is defined as a set of infrastructures, other structures, and buildings that create an environment to serve a population living within relatively small and confined geographic area (Kreimer et al., 2003). Cities have certain characteristics that make them unique, the most important ones being: the integration of different stakeholders who are responsible for the proper functioning of the city (Gimenez, 2017), the inclusion of different infrastructures, buildings and structures necessary for the wellbeing of the citizens, the responsibility of preserving the environment of the geographic area, and the obligation of providing the services required for the wellbeing of citizens. As cities continue to face more and more challenges, there is an urgent need to work towards building resilience in order to mitigate the effects of a wide spectrum of disasters, ranging from short term disasters such as floods, droughts and earthquakes to long term disasters such as climate change or environmental pollution (100 Resilient Cities, 2016). In recent years, the concept of resilience has become widely adopted in both policy and strategic reports as well as in academic studies (Kontokosta and Malik, 2018; Weichselgartner and Kelman, 2014). However, there is still not a unique, consensus-based definition that is valid for all areas of research. In fact, each field of study provides its own definition of resilience based on its particular characteristics (Weichselgartner and Kelman, 2014). Therefore, this present research narrowed the literature review to the concepts of city and urban resilience as a way to find papers applicable to the specific context of cities. In practice, governments and other institutions such as the UNISDR or Rockefeller Foundation have defined strategies and actions aimed at enhancing city resilience (Chmutina et al., 2016). In academic debates, most attention has been given to defining and characterizing resilient cities (Johnson and Blackburn, 2014). Based on existing studies, the following paragraphs analyze the most popular city resilience frameworks provided by international organizations and found within the academic literature.

Since 2010, the United Nations International Strategy for Disaster Reduction (UNISDR) has championed the need for building resilient cities through the *Making Cities Resilient campaign* (Johnson and Blackburn, 2014). The campaign outlines 10 actions necessary for a resilient city such as the need to be equipped with a competent and accountable local government and stakeholders who take actions to reduce the risks to disasters (Valdés et al., 2013). Moreover, a resilient city needs to be able to absorb future disasters with minimal or without any effects to the city, its physical systems and the community (Oteng-Ababio et al., 2015). Following the efforts made by the UNSIDR, in 2015 *the Sendai Framework for Disaster Risk Reduction* was developed with the objective of reducing disaster risks through an “all-of-society” and “all-of-State institutions” engagement approach that emphasizes the important role of governments and communities in reducing vulnerabilities and enhancing community resilience (UNISDR, 2015a).

Furthermore, as part of its mission to promote the well-being of humanity around the world, the Rockefeller Foundation developed within the 100 Resilient Cities program the *City Resilience Framework* for assessing and addressing resilience across a wide spectrum of stresses. The City Resilience Framework provides twelve indicators that describe the fundamental attributes of a disaster resilient city (100 Resilient Cities, 2016). In a recent study, Kontokosta and Malik (2018) presented the *Resilience to Emergencies and Disaster Index* (REDI). The REDI index is a benchmark for resilience, which measures the resilience capacity of cities and provides a performance measure according to four resilience categories: social infrastructure, physical infrastructure, economic strength, and environmental conditions. Both the *City Resilience Framework* and the REDI index provide indicators that assess a city's resilience level according to the defined resilience categories.

On the basis of existing frameworks in the academic literature, Desouza and Flanery (2013) define four strategies for improving resilience. These strategies include accepting the change and uncertainty inherent to cities, maintaining the social and ecological diversity and network capacity for recovery after disturbances, and creating knowledge generation and self-organizing capacities (Desouza and Flanery, 2013).

Moreover, Lu and Stead (2013) describes six characteristics of resilience towards climate change. First, they recognize the need to learn from previous experiences, both positive and negative (ability to learn) and the ability to involve the public and foster their participation in policy decisions. Second, they recognize the need to be aware and understand the existing conditions of the city (attention to current situation) and commit resources and initiate action to respond to issues such as climate change (ability to set goals and initiate actions). Furthermore, they emphasize the need to prepare for future disturbances on the basis of current information (attention to trends and future threats).

Finally, Oxley (2013) recognizes that strengthening resilience is a dynamic process that is embedded within the day to day activities. According to the author, the resilience-building process involves eight organizational actions that enhance adaptive capabilities to respond and adjust to an increasing and unpredictable array of disasters.

Taking into account academic studies and strategic reports from international organizations, a wide range of characteristics and priority areas for improving city resilience can be found. However, recent debates on building resilience outline the difficulties of incorporating resilience characteristics and priorities into practical or operationalized implementation (Collier et al., 2013). Existing frameworks outline characteristics and priority areas for cities to use as checklist rather than providing cities a roadmap that defines the optimal and sequential steps that cities should follow to build resilience (Cavallo and Ireland, 2014; Weichselgartner and Kelman, 2014).

Furthermore, not all cities are at the same in terms of their resilience level (Oteng-Ababio et al., 2015) and the presented frameworks do not provide the policies that a city should carry out depending of what it has already achieved (Jabareen, 2013). Actually, there are limited examples of how to operationalize the attributes and characteristics of resilient cities and the implementation of the resilience-building process is still lacking (Chmutina et al., 2016; Weichselgartner and Kelman, 2014). Furthermore, existing frameworks lack to provide the temporal order in which resilience-building policies should be put into practice (Weichselgartner and Kelman, 2014).

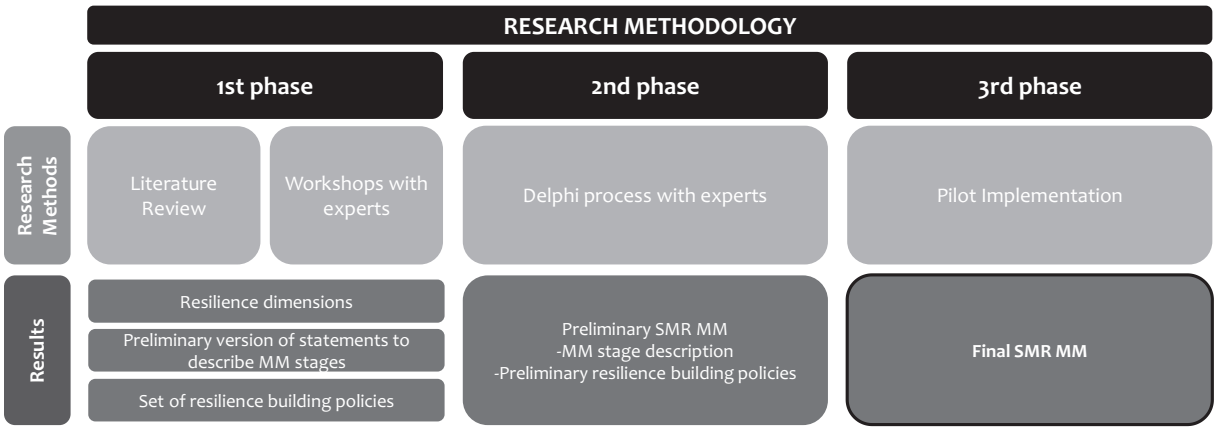

Fig. 1. Research methodology to develop the SMR MM.

2.1. Research contribution

Building resilience requires finding new ways to break down organizational silos among a wide range of city stakeholders such as the government, the private sector and citizens (UNISDR, 2015a; Weichselgartner and Kelman, 2014). Combining stakeholders' material resources, experience, knowledge and expertise enables them to identify how to best operationalize the resilience-building process (Spaans and Waterhout, 2017). In this context, existing frameworks fail to provide city stakeholders with a roadmap that presents a detailed temporal order in which the policies should be implemented in practice to efficiently operationalize the resilience-building process (Cavallo and Ireland, 2014; Jabareen, 2013).

Given the gaps in the resilience operationalization process, the contribution of the SMR project is the development of a Maturity Model (SMR MM) that cities can use as a roadmap for effectively assessing and improving their resilience-building process from a holistic perspective. A Maturity Model (MM) is defined as a structured sequence of stages that helps entities address problems and challenges by providing a benchmark against which to compare the evolution of the process and a roadmap for improving them (Caralli et al., 2012; Becker et al., 2009). It describes the trajectory of an organization over time and through stages of increasing maturity, as measured by the capability to perform some process (Wendler, 2012). The SMR MM defined in this research describes the evolution of effective processes at different stages of development, from an initial stage to a more advanced stage (Antunes et al., 2014; Caralli et al., 2012; Wendler, 2012). The SMR MM allows a city to define its current state based on the maturity stages and determine the actions and policies it should implement in the future to advance to higher maturity stages (Caralli et al., 2012). The tool has been developed as a general tool for all the city stakeholders, but in particular, for decision makers at the city level responsible for building city resilience in order to know the roadmap towards becoming a resilient city.

The SMR MM was developed through a multi-methodological procedure and a co-creation approach that involved a variety of experts from local, regional and national governments, academic and scientific entities, and public and private companies, all of whom are knowledgeable about the resilience-building process with regard to critical infrastructure interdependencies, climate change adaptation and social dynamics (Becker et al., 2009). This paper explains the results obtained from this co-creation process, which served as input for the development of the final version of the SMR MM. The SMR MM comprises a sequence of five maturity stages that cities need to follow to achieve the objectives of a more advanced maturity. This SMR MM provides a description of each maturity stage and defines from a strategic level, the policies that need to be developed in order to move from a lower stage to a more mature stage, identifying the maturity stage in which each policy should start.

3. Research methodology

This research has been developed under the umbrella of the SMR European project, which involved seven city partners. One of the main tools developed in this project is the SMR MM, which aim at providing a roadmap to the cities for effectively assessing and improving their resilience level. This tool was developed as part of the co-creation process used to gather the requirements and needs of cities regarding the SMR MM and understand the process of building resilience. Having experts with different backgrounds and working in different disciplines related to city resilience made adopting a co-creation approach in the development of the SMR MM feasible by applying different but complementary methodologies such as a literature review, group model building workshops, and the Delphi process. Furthermore, the preliminary version of the SMR MM obtained from the Delphi process was validated through three pilot implementation workshops in three European cities. In turn, this co-creation approach facilitated mutual learning and the establishment of relationships and trust between the different stakeholders taking part in this co-creation process (Frantzeskaki and Kabisch, 2016).

This co-creation process was divided into three phases (see Fig. 1). In the first phase, through a literature review and workshops with experts, the following aspects were defined: the four resilience dimensions, the statements for describing the maturity stages and a set of policies that fulfill the objectives of each maturity stage. In the second phase, using a Delphi process, the descriptions of the maturity stages were validated and the preliminary implementation order of the resilience building policies was determined by establishing the starting stage and the ending stage of each policy. Finally, the three pilot implementation workshops were carried out in order to improve and validate the preliminary version of the SMR MM obtained from the Delphi process.

3.1. First phase: literature review and group model building workshops with experts

The aim of this first stage was to define the resilience dimensions, to determine the statements for describing the maturity stages and to identify a set of policies for improving the resilience level of the cities. These results were afterwards used as input for the Delphi process. In order to do that, first a literature review of academic journals, reports written by different worldwide institutions and research projects related to city resilience was carried out in order to define the four resilience dimensions explained in the results section (Section 4.1).

Furthermore, a set of resilience building policies that help improve the resilience level of the cities and move to a more advanced stage were identified through this literature review.

Then, four workshops with experts in the field of resilience were carried out in order to identify valuable information that helps us to better understand the evolution of the resilience-building process. These workshops were conducted using the group model building (GMB) methodology. GMB is a collaborative methodology that enables fragmented knowledge, initially residing in the minds of different agents, to be integrated into aggregated knowledge (Richardson and Andersen, 1995). This methodology is based on workshops where multi-disciplinary experts work on the problem jointly using specific exercises that support efficient collaboration. The information gathered in each workshop is analyzed and used as basis for the next workshop. This iterative process and the fact of having multi-disciplinary experts with different backgrounds increase the value of the input provided by participants.

Given that city resilience is a wide scope concept, the participation of multidisciplinary experts in the workshops is essential to gaining a holistic view of the problem. The main aim of these one-day workshops was to define the statements that describe the SMR MM stages and to find additional resilience policies to the ones previously identified in the literature review.

The workshops were held in four partner cities (Riga, Bristol, Rome and Vejle) and city representatives from the seven city partners from different areas such as environmental management, infrastructure protection and social issues took part in the workshops (see Table 1). An iterative process was carried out were the results from the previous workshops were validated and improved in the following workshops.

The first workshop was held in Riga, and it facilitated the identification and classification of the most relevant milestones carried out in each of the seven city partners in the process of building resilience. Moreover, this first workshop set the basis for common understanding among experts about the concept of city resilience. The second workshop was held in Bristol, and the potential resilience-building policies that had been implemented and should be implemented at a city level were identified. Furthermore, the barriers and challenges found when implementing these policies were also defined. The third workshop took place in Rome, and participants consolidated the resilience-building policies previously identified and defined their dynamics, as well as proposing statements that described each MM stage. Finally, in the fourth workshop, held in Vejle, experts improved and validated resilience-building policies and their dynamics and accordingly improved the descriptions of the maturity stages. A detailed explanation of the activities carried out and the concrete results obtained in each workshop can be found in the references in Table 1.

The results gathered at each workshop were improved following an iterative process in subsequent workshops. In this first phase, the statements that define each maturity stage were obtained and the list of policies that help build city resilience was compiled and classified based on the four resilience dimensions identified through the literature review. Once all this information was identified and analyzed, it was used as input for the Delphi process.

3.2. Second phase: Delphi process

Based on the results obtained from the first phase, a Delphi process with a different group of multi-disciplinary experts in the field was carried out to validate the statements that describe the maturity stages and classify the resilience-building policies in the maturity stages identifying in which maturity stage the implementation of each policy should start and end. The Delphi methodology was selected since it is well-suited to consensus-building processes related to a complex problem through a systematic and iterative process using a set of questionnaires to collect data from a panel of selected experts (Dalkey, 1969; Linstone and Turoff, 1975; Okoli and Pawlowski, 2004). The Delphi method was originally designed to reduce confrontation and inhibiting effects within interacting groups through anonymity, while at the same time retaining the power of the combined knowledge of a group of experts (Dalkey, 1969; Linstone and Turoff, 1975). It consists of multiple rounds of questionnaires and feedback among experts in order to refine the results (Skulmoski et al., 2007). The advantage of the Delphi method is that it saves time and costs for both participants and researchers, as the questionnaire can be completed remotely (Delbecq et al., 1975). However, on the downside, the Delphi approach does not provide opportunities for interaction or clarification of ideas with other experts (Nelms and Porter, 1985).

In terms of the number of participants that should take part in the process, Delbecq et al. (1975) propose that the sample should be between ten and fifteen people in the case where the sample is homogeneous. If participants are heterogeneous, Linstone and Turoff (1975) propose that four to five experts from each field are needed to perform the process.

The Delphi methodology used within the SMR project consisted of two rounds (see Fig. 2). The purpose of the first round was to validate the statements that describe the five maturity stages of the SMR MM. In order to do that, experts had to review the statements of each maturity stage and indicate to what extent they agreed with them using a five-level scale to measure levels of agreement/disagreement, from strongly disagree to strongly agree. Moreover, an open-ended question was included in the questionnaire to allow experts to propose new statements that could improve the definition of each maturity stage.

In the second round of the Delphi process, participants were asked to first re-evaluate the questions from the first questionnaire for which the experts did not reach a consensus (the criteria used to establish the consensus is defined in the results section), and then to classify the resilience-building policies in the maturity stages. In order to do that, the experts were asked to first determine in which maturity stage the policy should start being implemented, and then to establish in which maturity stage the policy should finish being implemented.

In the first round of the Delphi process, 40 experts (56.33%, 40 out of 71) agreed to collaborate although only 32 (45%) experts completed the entire process (see Fig. 2).

The panel of experts was composed of multidisciplinary experts with different backgrounds and expertise, some with more holistic background about crisis management and others with more particular one based on the three problem areas defined in this project (see Table 2). All the experts were invited to answer the whole questionnaire regardless of their background since we considered all of them had sufficient expertise to answer all the questions. These experts were

Table 1
Organization of the four workshops and the number of experts in each of them.

Workshop	Place	No. of experts	Reference
Workshop 1	Riga (Latvia)	20	(Smart Mature Resilience, 2016b)
Workshop 2	Bristol (U.K.)	15	(Smart Mature Resilience, 2016c)
Workshop 3	Rome (Italy)	13	(Smart Mature Resilience, 2016d)
Workshop 4	Vejle (Denmark)	16	(Smart Mature Resilience, 2016e)

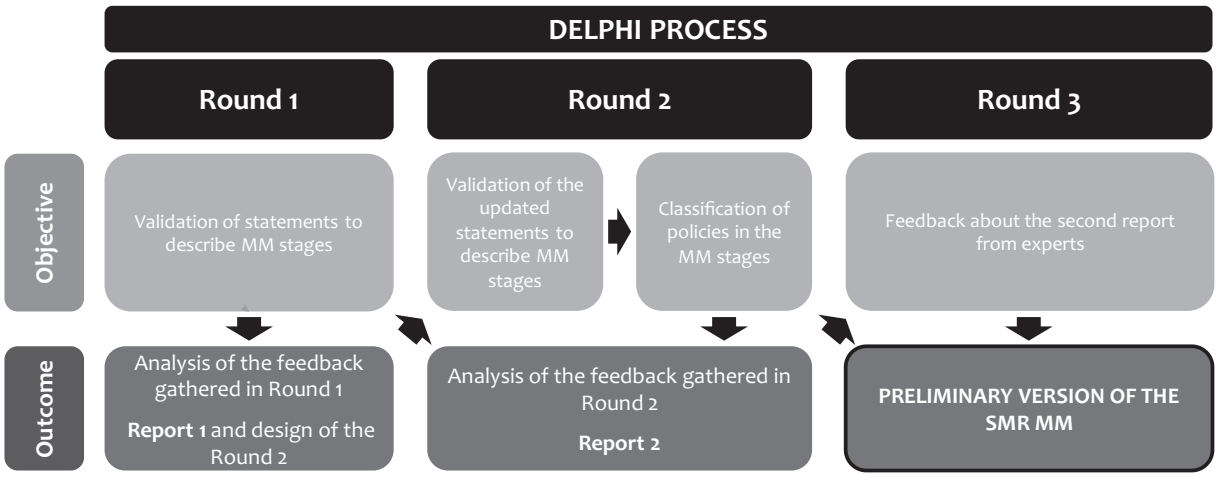

Fig. 2. Delphi process.

Table 2
Number of experts in each round classified according to their background.

	Participants in the first round	Participants in the second round
Critical infrastructures	9	7
Climate change	8	8
Social issues	10	6
Holistic crisis management	13	11
Total	**40**	**32**

different from the experts that took part in the workshops carried out in the first phase in order to contrast the obtained results with different experts.

3.3. Third phase: pilot implementation workshops

After conducting the Delphi process, three pilot implementation workshops were carried out in the cities of Kristiansand (Norway), Donostia-San Sebastian (Spain) and Glasgow (United Kingdom) to improve and validate the usefulness of the model. During these pilot implementations, the participants assessed their current maturity level based on the four resilience dimensions. Furthermore, they identified the policies and actions that should be implemented in the future to advance to the next MM stage. Furthermore, during these workshops, the experts provided feedback and commented on areas of improvement to enhance the SMR MM according to their needs.

Each workshop invited 10–12 multidisciplinary experts to work on the four resilience dimensions defined in the SMR MM (see Fig. 3). During the pilots, the experts were asked to identify evidence for the concrete examples of actions undertaken in each maturity stage by going through the policies included in the five maturity stages. For each policy, they had to specify three things: the activities and initiatives implemented to perform this policy, when each implementation started and the timeline for arriving at full implementation, and the barriers, difficulties and challenges encountered during implementation. That way they were able to identify their current maturity stage in each of the four resilience dimensions and the policies that needed to be implemented in order to move further along the resilience-building process. Smart Mature Resilience (2017) describes in great detail the experts that took part in the pilot workshops, the activities performed and the results obtained in each city.

4. Results obtained during the co-creation process

The developed SMR MM consists of five stages, four dimensions and a set of policies classified based on the stages and dimensions. This section explains the results obtained through the co-creation process that provided input for the development of the SMR MM. The first sub-section explains the resilience dimensions, the second sub-section describes the maturity stages defined in the SMR MM, the third sub-section illustrates the classification of the resilience policies based on the maturity stages defined by the results of the Delphi process. The last sub-section presents the feedback given and the areas of improvement identified during the pilot implementation workshops.

4.1. Definition of the resilience dimensions

Based on the literature review, this research proposes four resilience dimensions that cover the characteristics and priority areas that need to be improved to build resilient cities: 1) *Leadership & Governance*, 2) *Preparedness,* 3) *Infrastructure & Resources*, and 4) *Cooperation*. As emphasized by the analyzed frameworks (Kontokosta and Malik, 2018; Lu and Stead, 2013; Oxley, 2013; UNISDR, 2015a; UNISDR, 2015b), moving closer to ensuring resilient cities requires an integrated approach to city planning and development across governmental institutions (*Leadership & Governance*). A resilience-focused approach also emphasizes the need to be prepared to a wide range of disasters, both short-term and long-term disasters, that are not necessarily predictable (*Preparedness*) (Desouza and Flanery, 2013; Lu and Stead, 2013; 100 Resilient Cities, 2016). Furthermore, building resilience requires enhancing the performance of the city's infrastructures in the face of multiple disasters, rather than preventing or mitigating the loss of assets due to specific events (*Infrastructure & Resources*) (100 Resilient Cities, 2016; UNISDR, 2015b; Kontokosta and Malik, 2018). Finally, building city resilience is a complex process that requires taking actions to engage a wide variety of stakeholders such as the society, private and public sector (*Cooperation*) (Desouza and Flanery, 2013; Oxley, 2013; Lu and Stead, 2013; UNISDR, 2015b; 100 Resilient Cities, 2016; Kontokosta and Malik, 2018). The defined four resilience dimensions have been used to classify the characteristics and priority areas presented in Table 3. Following, the descriptions of the four resilience dimensions are provided:

- **Leadership & Governance (L&G)** refers to the leaders' commitment to promoting culture, values and vision and implementing effective strategies, inclusive decision-making and the engagement of relevant city stakeholders in the resilience-building process. In order to achieve this, municipality, cross-sectorial and multi-governance collaboration and legislation needs to be developed and refined. Furthermore, learning culture among different stakeholders need to be fostered.

Fig. 3. A photo from the pilot implementation workshop in Donostia-San Sebastian.

- **Preparedness (P)** refers to the anticipation of expected and unexpected disasters and taking measures to increase the flexibility and adaptive capacity accordingly. In order to improve the level of preparedness of a city it is necessary to carry out a diagnosis and assessment of potential disasters and existing plans and procedures. Furthermore, education and training programs need to be carried out to improve the level of preparedness of stakeholders such as citizens, communities and governmental institutions
- **Infrastructure & Resources (I&R)** refers to allocating the required resources (i.e. assets, people, skills, information, technology) to increase the robustness and resistance level of infrastructures. In this vein, the reliability of critical infrastructures and their interdependences need to be assessed. Furthermore, resources for building up the resilience and the response of infrastructure need to be deployed.
- **Cooperation (C)** refers to working or acting together at the local, regional, national and international level for a common purpose or benefit. Cooperation needs to be fostered by developing partnerships between city stakeholders (companies, volunteers, citizens…). Furthermore, alliances with other cities need to be established by the involvement of the city in resilience networks of cities. This involvement contributes to the exchange of best practices and common learn with other cities about the resilience-building process.

These proposed resilience dimensions, supported by the literature, allow us to classify the resilience-building policies identified in the literature review and through the GMB workshops with experts.

4.2. Description of the maturity stages

This sub-section focuses on explaining how the statements used to describe the different maturity stages of the SMR MM have been defined and validated. As previously noted in the methodology section, a list of statements obtained from the resilience literature and from the workshops conducted with experts were defined in order to describe the objectives to be achieved in each maturity stage. Each of the SMR MM stages has been described using a set of statements that cover the four resilience dimensions proposed (see Section 4.1). In order to validate these statements, in the first step of the Delphi process, experts were asked to indicate on a five point Likert-type scale (strongly agree, agree, moderately agree, disagree, strongly disagree) the extent to which they agreed with the proposed statements in describing the five different SMR MM stages: Starting (S), Moderate (M), Advanced (A), Robust (R) and verTebrate (T).

The criterion used to determine that a statement describes in a suitable way each maturity stage is to see whether the statement has reached consensus. A statement is considered to have reached consensus among experts when the sum of the values in strongly agree and agree or the sum of the values in agree or moderately agree reaches 70%. When one of these percentages reaches 70% we consider the statement as being valid for properly describing the SMR MM stage.

If this criterion is not fulfilled, the statement cannot be considered valid. The non-validated statements were either removed, or reformulated based on the comments and suggestions made by experts and then included in the second round of the Delphi questionnaire. If consensus was not achieved in the first round, the statement was modified based on the comments from experts and it was asked again in the second round of the process.

- Starting SMR MM Stage:
  In the starting stage, the resilience-building process is focused on risk assessment, without taking an integrated multi-hazard approach, and on preparing for already identified threats and without considering unexpected events. Furthermore, the resilience-building process is still fragmented, since relevant stakeholders and departments work in silos without considering the need to coordinate and integrate their efforts and outcomes. The local government recognizes the need to develop an integrated action plan with a common strategy. The resilience-building process is limited to within the city's borders and there is a lack of collaboration with suburban or regional stakeholders and resilience networks.
- Moderate SMR MM Stage:
  In the moderate stage, the city sets up the organizational structure to manage the resilience action plan. At the same time, a communication strategy that will increase the awareness level of the different municipal departments and scale up resilience-building efforts to foster a resilience culture within them is developed. The resilience action plan includes a risk assessment for expected events that affect critical infrastructures and man-made threats, and it is operationalized in cooperation with critical infrastructure providers. Furthermore, it proposes policies that need to be prepared and that are able to respond to unexpected events using a holistic approach. The city monitors the implementation of resilience development policies by using control measures, although there is a lack of a formalized resilience management process. Finally, the local authority recognizes the relevance of a multi-governance approach and acts accordingly to strengthen this approach and also starts planning for networking with other cities around the world with regard to resilience.
- Advanced SMR MM Stage:
  In the advanced stage, an integrated and holistic resilience-building

Table 3
Classification of the attributes of resilient cities into the four resilience dimensions.

Frameworks (year)	Resilient cities attributes and characteristics	L&G	P	I&R	C
Sendai Framework for Disaster Risk Reduction 2015-2030 (UNISDR, 2015a)	Understanding disaster risk		X		
	Strengthening disaster risk governance to manage disaster risk	X			
	Enhancing disaster preparedness for effective response in recovery, rehabilitation and reconstruction.	X	X		
	Investing in disaster risk reduction for resilience			X	
10 Essentials (UNISDR, 2015b)	Increase infrastructure resilience			X	
	Organize for disaster resilience	X			
	Identify, understand and use current and future risk scenarios.		X		
	Ensure effective disaster response	X	X		
	Pursue resilient urban development and design	X		X	
	Expedite recovery and build back better				X
	Understand and strengthen societal capacity for resilience				
	Safeguard natural buffers to enhance ecosystems' protective functions	X			
	Strengthen financial capacity for resilience			X	
	Strengthen institutional capacity for resilience	X			
City Resilience Framework (100 Resilient Cities, 2016)	Ensures continuity of critical services			X	
	Provides and enhances natural and manmade assets	X			
	Fosters long term and integrated planning		X		
	Meet basic needs	X			
	Ensure public health services	X			
	Ensure social stability, security and justice.	X			
	Supports livelihoods and employment	X			
	Promotes cohesive and engaged communities				X
	Empower a broad range of stakeholders				X
	Fosters economic prosperity			X	
	Provides reliable communication and mobility			X	
	Promotes leadership and effective management	X			
Resilience to Emergencies and Disaster Index (Kontokosta and Malik, 2018)	Social infrastructure and community connectivity				X
	Physical infrastructure			X	
	Economic strength			X	
	Environmental conditions	X			
Desouza and Flanery (2013)	Assume change and uncertainty		X		
	Nurture conditions for recovery and renewal after disturbance	X	X		
	Combine different types of knowledge for learning	X	X	X	X
	Create opportunities for self-organization				X
Lu and Stead (2013)	Attention to the current situation			X	
	Attention to trends and future threats		X		
	Ability to learn from previous experience	X	X	X	X
	Ability to set goals	X			
	Ability to initiate actions	X			
	Ability to involve the public				X
Oxley (2013)	Preparedness		X		
	Responsiveness		X		
	Connectivity				X
	Learning	X	X	X	X
	Self-organization		X		
	Diversity	X			X
	Inclusion	X			X
	Social cohesion	X			X

plan is developed and integrated within the different departments and areas. The progress of the city resilience action plan is monitored, gathering information on the progress and effectiveness of the implemented policies. The resilience action plan implements a risk assessment that includes measures to rapidly bounce back (getting everything working again) and bounce forward (taking opportunities as they come along to thrive under change). Furthermore, the resilience action plan defines measures to increase the flexibility of city infrastructures in dealing with unexpected events and to adapting to on-going circumstances. The resilience building plan fosters cooperation and commitment of different city stakeholders, such as public and private entities and citizens, in the resilience-building process. The multi-governance approach with a European dimension is also included in the plans but not yet fully operationalized. The city is member of a major network of European cities with regard to resilience. Finally, the resilience learning process is formalized through regular debriefing meetings to identify best practices in resilience.

- Robust SMR MM Stage:

In the robust stage, the resilience-building plan is improved and updated continuously based on the lessons learned from previous crises and on the regularly collected information from the stakeholders through consultation processes and participatory platforms. All the city stakeholders are part of the resilience building process and play a proactive role, and they perceive the value added of resilience on their quality of life and economy. The resilience-building plan makes the city capable of bouncing back, bouncing forward, and ensuring protection from impacts for expected and unexpected events. Finally, the multi-governance approach with a global dimension is well developed and operationalized, and the city

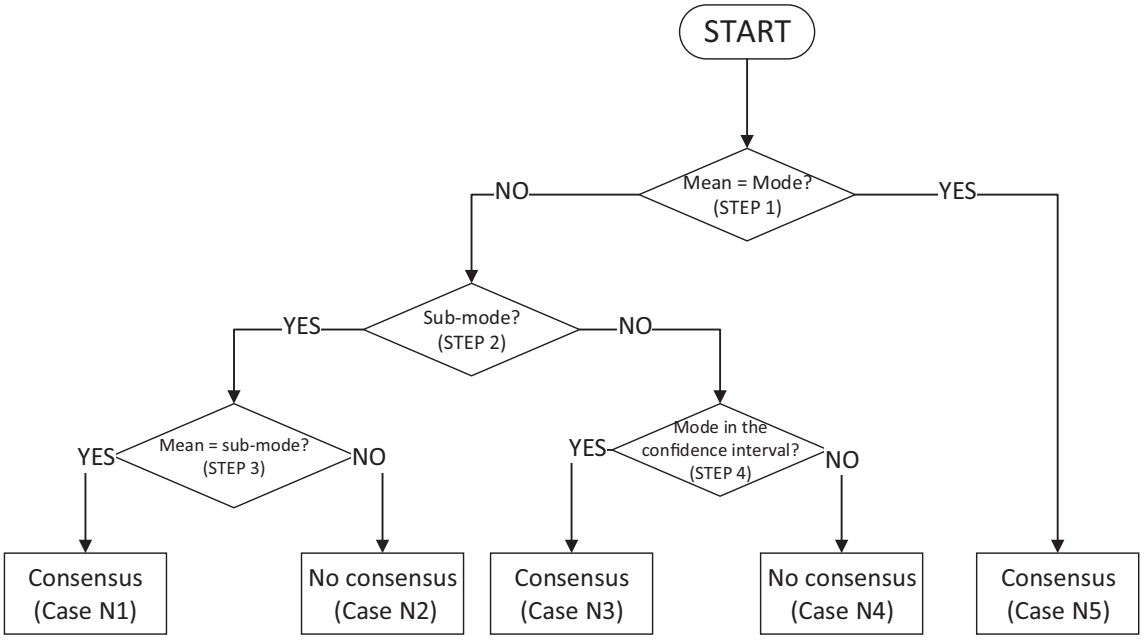

Fig. 4. The flow diagram that represents the analysis carried out with the results from the Delphi process.

Table 4
Results from the Delphi process about when the policies within Infrastructure and Resources dimension start and end.

								Infrastructure & Resources (I)					
		S	M	A	R	T	Don't know	Mean stage	Mode stage	Sub-mode stage	Confidence interval		Resulting stage
I1. Develop measures to increase Critical Infrastructure (CIs) redundancy.	Start	10	15	5	0	0	2	M	M	N/A	M	M	M
	End	0	4	7	10	7	4	R	R	N/A	A	R	R
I2. Develop measures to increase CI flexibility.	Start	5	21	5	0	0	1	M	M	N/A	M	M	M
	End	0	5	8	9	7	3	R	R	N/A	A	R	R
I3. Develop periodical maintenance procedures to guarantee the correct performance level of CIs.	Start	10	10	9	1	0	2	M	S, M	N/A	M	M	M
	End	1	4	11	6	6	4	A	A	N/A	A	R	A
I4. Develop a contingency plan aimed at keeping CIs functioning at a minimal level in a disaster.	Start	13	12	3	2	0	2	M	S	M	S	M	M
	End	2	5	10	6	6	3	A	A	N/A	A	R	A
I5. Develop early warning, monitoring systems to alert for potential emerging risks.	Start	11	14	4	2	0	1	M	M	N/A	M	M	M
	End	1	7	9	10	4	1	A	R	A	A	R	A
I6. Develop an incentive system for public and private sectors to promote the investment in measures that increase resilience and penalties for those who increase the risk and vulnerabilities.	Start	0	10	15	3	2	2	A	A	N/A	A	A	A
	End	0	1	2	8	19	2	T	T	N/A	R	T	T
I7. Set up a disaster relief fund for emergencies.	Start	5	8	8	4	1	6	A	M, A	N/A	M	A	A
	End	2	2	4	6	12	6	R	T	–	A	R	No consensus

participates in and promotes important international city networks related to resilience.

- Vertebrate SMR MM Stage:
  In the last stage, the city has the capacity to self-organize in building the resilience level of the city with high levels of participation in the decision-making process from all the city stakeholders and its resilience level is continuously improved. It understands that in order to become resilient the environment needs to be resilient as well. The city becomes a reference city in Europe regarding resilience, thus contributing to the creation of a European Resilience Backbone (Gonzalez et al., 2017).

In analyzing the results and comments received from experts in the first section of the Delphi questionnaire, we came up with two main conclusions. The first one was that some of the experts thought that the statements used to describe the starting and moderate stages were too demanding. They argued that certain previous requirements were needed before the SMR MM could be used as a valuable supporting tool, and as a result, they suggested having a maturity stage prior to the starting stage. However, the tool was defined with the aim of supporting the resilience-building process and therefore, it is assumed that the cities using the tool should have a certain level of awareness and commitment towards resilience. For example, they should have allocated a portion of their budget to increase awareness towards resilience

Table 5
Resilience dimensions and sub-dimensions.

Resilience dimensions	Resilience sub-dimensions
Leadership and Governance	Municipality, cross-sectorial and multi-governance collaboration
	Legislation
	Learning culture (learning and dissemination)
	Resilience plan development
Preparedness	Diagnosis and assessment
	Education and training
Infrastructure and Resources	Reliability of infrastructures
	Resources to build up resilience
Cooperation	Development of partnerships with city stakeholders
	Involvement of resilience networks in cities

or considered this problem as a strategic problem for the city before starting to use this tool. For these reasons, we did not include a new stage prior to the starting stage.

The second main conclusion found was that although experts agreed on the statements suggested to describe the rest of the stages (advanced, robust and vertebrate) some of them argued that the last stage of the Maturity Model, the vertebrate stage, should be dynamic and adjustable rather than fixed. As it currently stands, the vertebrate stage is described as the ideal stage that cities should aspire to. However, as long as cities context evolves and city stakeholders keep on investing resources in the city resilience-building process, the vertebrate stage will adapt and adjust accordingly in the future.

4.3. Resilience policies and their classification in the maturity stages

The resilience policies were defined based on the literature review and the four workshops carried out in the four cities defined in the methodology section, and they were classified by taking into account the four resilience dimensions defined in the literature review: leadership and governance (L), preparedness (P), infrastructure and resources (I) and cooperation (C).

Once the resilience policies were defined, they were classified within the appropriate maturity stages through the second questionnaire in the Delphi process. For each policy, the experts had to select within which of the five MM stages (S, M, A, R, T) the policy should start being developed and by which stage it should be fully developed, given the description of each maturity stage. The process used to analyze the data obtained is explained and, as an example, the results obtained in the Infrastructure and Resources dimension are presented below.

For each policy, the experts stated when the implementation of the policy should start and end. Based on the data obtained from the experts, the mean stage and the mode stage were calculated. Furthermore, the sub-mode stage was also calculated which was defined as the stage that received the second highest number of votes and where the number of responses received for the mode stage and the sub-mode stage differed by no more than two. The confidence interval of the mean stage at a 95% confidence level was also calculated. Finally, based on the previously calculated parameters, the resulting stage was assessed, which determines when the policy should start and end up being implemented. In order to calculate these values, we follow the logic described in the flow diagram illustrated in Fig. 4.

First, we compared the mode stage and the mean stage in each case (Step 1 in Fig. 4). If both stages were the same, we concluded that there was consensus regarding which stage policy implementation should start or end in. In 56 out of 86 cases the mean stage and the mode stage matched (look at Table 4).

If both stages were different, then we analyzed whether there was any other stage, which received a substantial number of responses, that we called sub-mode stage (Step 2 in Fig. 4). We defined the sub-mode stage as the stage that received the second highest number of votes and where the number of responses received for the mode stage and the sub-mode stage differed by no more than two, i.e., if a stage receives only one or two fewer responses than the mode stage, it is a sub-mode stage. These sub-mode stages have been highlighted in Table 4 with a lighter color and are also indicated in the column called “Sub-mode Stage”. In the cases where there is a sub-mode value, then we compared whether the sub-mode stage was the same as the mean stage (Step 3 in Fig. 4). If the sub-mode stage and the mean stage matched (case N1), we considered there to be consensus regarding the stage in which the policy should start or end its implementation, where the resulting stage is either the mean stage or the sub-mode stage.

In the case where the sub-mode value did not match the mean value, this meant that the responses were dispersed and there was no agreement on the results (case N2). This happened mainly when the policies were defined with a broad scope. Therefore, the broad and general definition of these policies may have led to different understandings of their scope. In these cases, the results were dispersed throughout all the stages, and therefore there was no consensus about when the policy's implementation should start or end.

Finally, in cases where there was no sub-mode stage, we verified whether the mode stage was within the confidence interval of the mean stage (Step 4 in Fig. 4). If the mode stage was within the interval (case N3), then we could say there was consensus in the responses, and as a result the starting or ending stage would not be a concrete stage but somewhere between the mode stage and the mean stage. If the mode stage was not within the confidence interval (case N4), we could not arrive at a consensus in the responses, and therefore we could not define in which stage the implementation of the policy should start or end. In most of the cases, this lack of consensus occurred when determining the end of a policy's implementation. This is because in practice we always need to allocate some resources and effort to ensure that the policy is effective and updated constantly to the city's needs.

As an example, Table 4 shows the detailed results from the Delphi process for the Infrastructure and Resources dimension and how the resulting stages were determined. The numbers below the stages (S, M, A, R, T) represent the number of respondents that think that the policy should start or end in this stage. The mean stage column represents the mean stage based on the responses obtained. The mode stage is the stage that received more answers from the respondents and it has been highlighted in each case with a darker color. This information is also indicated in the column called “Mode Stage”. The sub-mode stage column shows the sub-mode stages that have been defined in this research in order to carry out the analysis. This concept was further explained above. The next column represents the confidence interval of the mean stage at a 95% confidence level. Finally, the last column represents the resulting stage, which determines when the policy should

Table 6
Disaggregation of the I4 policy defined in the Delphi process into four policies.

Policy in the Delphi process	Policies in final version of the SMR MM
I4 - Develop a contingency plan aimed at keeping CIs functioning at a minimal level in a disaster	I1S2 - Develop plans to monitor CI functionality
	I1S3 - Develop contingency plans for CIs
	I1M1 - Identify interdependencies of critical services at local level
	I1R1 - Identify interdependencies of critical services at international level

Table 7
The resilience policies defined at the vertebrate stage as a result of the pilot implementations.

Resilience dimension	Resilience sub-dimension	Resilience policies in the vertebrate stage
Infrastructure and Resources	Reliability of infrastructures	I1T1 - Encourage the continuous improvement of policies in order to take advantage of any shock and stress to bounce forward and improve or re-design I1T2 - Apply big data approaches to analyzing information
	Resources to build up resilience	I2T1 - Assess the impact of innovation in the resilience-building process. I2T2 - Monitor the insurance level of stakeholders

start and end up being implemented, based on the analysis of the responses described above and in Fig. 4. Smart Mature Resilience (2016f) collects all the detailed results obtained from the Delphi process for all the resilience dimensions.

4.4. Improvements to SMR maturity model

As a result of the three pilot implementations, the SMR MM was improved in order to be more useful for the cities and fulfill their needs. The main changes implemented in the model are explained below.

One comment made by several experts was that the implementation of the policies never ends; that is, once a policy is implemented some maintenance resources need to be allocated to update the policy accordingly. Furthermore, during the Delphi process, for several policies it was not possible to achieve a consensus as to when these policies should stop being implemented. Therefore, the final version of the SMR MM only defines when each policy should start being implemented without specifying when the implementation should finish.

Another comment regarding the resilience dimensions was that the scope of the resilience dimensions defined in the SMR MM was relatively broad. A large number of policies were grouped into the same dimension even though the context they were addressing was sometimes slightly different. We found that using only four resilience dimensions to classify all the policies included in the SMR MM was not always sufficient. Therefore, we clustered the policies into resilience sub-dimensions, with a narrower scope, to facilitate the understanding of the evolution of each policy through the maturity stages. Table 5 defines the resilience sub-dimensions defined for each resilience dimension.

Similar the previous comment, the experts thought that several policies defined in the Delphi process were very broad and covered several maturity stages. Therefore, they suggested specifying them further in order to make the implementation of the policies easier in practice and define in more detail what is expected in each of the maturity stages. Therefore, several policies were divided into more than one, each evolving over the maturity stages. For example, the policy "I4 – Develop a contingency plan aimed at keeping CIs functioning at a minimal level in a disaster" defined within the Infrastructure and Resources dimension (see Table 4) is very broad: the verb 'develop' has a broad meaning and includes actions such as planning, implementing, assessing, monitoring and improving. Furthermore, within the contingency plans we can include several aspects such as response procedures, a list of critical services at a city level, an analysis of interdependences among critical infrastructures, etc. Therefore, this policy was divided into 4 policies in the final version of the SMR MM, as shown in Table 6.

Finally, validating the policies included in the Vertebrate stage was difficult since none of the cities had reached this stage yet. Therefore, we defined it as a hypothetical stage and we asked experts to define what policies would need to be developed in order to reach this vertebrate stage. As a result, new policies were added to the maturity model in order to define the actions that should be implemented in this last maturity stage. For example, in the case of the Infrastructure and Resources dimension, the following four resilience policies were defined for the Vertebrate stage (see Table 7). Due to the need to continuously improve this final stage, the experts claimed that its description should be flexible enough to include the new innovative policies, procedures and activities that will arise in the future.

5. The Smart Mature Resilience Maturity Model

The following tables show the four dimensions of the SMR MM and the policies defined by each maturity stage.

The Leadership and Governance dimension (Table 8) is divided into four sub-dimensions. The first one is related to the collaboration between governances at different level. In this sub-dimension, the policies are oriented towards creating a resilience department and aligning and integrating different resilience perspectives at different governance levels (municipality, regional, and national). The second sub-dimension focuses on legislative aspects establishing how the certifications and standards should be defined and integrated at different scales. The third sub-dimension refers to the learning process and the policies within this sub-dimension define the progressive path towards improving the learning and knowledge sharing among different stakeholders and creating the learning culture within the city. The last one concentrates on developing the city resilience plan and it establishes the different steps towards developing and sharing the resilience plan with other cities.

The Preparedness dimension (Table 9) is divided into two sub-dimensions. The first one is related to the diagnosis and assessment of risks. In order to be well prepared, it is important to make a risk analysis identifying the potential risks which can threaten our city. Furthermore, the interdependencies among these risks and their short-term and long-term consequences should also be taken into account according to the policies included in this sub-dimension. In the second sub-dimension, the education and training related aspects are established. The policies within this sub-dimension define the steps that should be taken into account to improve the training of the different stakeholders of the city including training sessions and emergency drills. Furthermore, policies to organize different education programs to enhance city resilience for different stakeholders are also defined within this sub-dimension.

Similarly to the previous one, in the Infrastructures and Resources dimension (Table 10) two sub-dimensions are defined. The first one is called "Reliability of Infrastructures" and it aims to define the roadmap towards ensuring the safety and reliability of the critical infrastructures of the city taking into account their interdependencies. Furthermore, policies to define the plans and procedures required for ensuring the proper functionality of the infrastructures are established. The second sub-dimension refers to the allocation of resilience building resources establishing the policies that need to be implemented from the lower maturity stages to the higher maturity stages. Policies related to insurance coverages to respond and recover from crises as well as the ones related to incentives for investing in research to improve resilience are also included within this sub-dimension.

Finally, the last dimension, Cooperation (Table 11), is divided into two sub-dimensions. The first one is related to defining the path to improve the partnerships among all the city stakeholders, that is, different governance entities, private companies, emergency services, citizens, NGOs, media etc. How to improve the communication among them, how to develop formal partnerships integrating all the stakeholders, how to create collaborative networks are some of the

Table 8
Smart Mature Resilience Maturity Model: Leadership and Governance dimension (Hernantes et al., 2019).

		STARTING	MODERATE	ADVANCED	ROBUST	VERTEBRATE
LEADERSHIP & GOVERNANCE	**Municipality, cross-sectorial and multi-governance collaboration (L1)**	**(L1S1)** Establish a working team responsible for resilience issues in the city	**(L1M1)** Establish a resilience department or committee and a cross departmental coordination board and procedures	**(L1A1)** Align, integrate and connect the resilience action plan with national plans	**(L1R1)** Align, integrate and connect the city resilience plan with regional, national and international resilience management guidelines	**(L1T1)** Support the development of other city resilience plans aligned, integrated and connected with regional, national and international resilience management guidelines
		(L1S2) Integrate resilience into visions, policies and strategies for city development plans	**(L1M2)** Align, integrate and connect the resilience action plan with regional plans	**(L1A2)** Develop a plan for multi-level governance approach involving the municipal, regional and national levels of governance		
			(L1M3) Adopt climate change preventive actions			
			(L1M4) Promote equality of access to services and basic infrastructure to vulnerable sector of society			
	Legislation (L2)		**(L2M1)** Develop a white paper about multi-level governance approach	**(L2A1)** Conduct certification processes to achieve the conformity with national standards	**(L2R1)** Conduct certification processes to achieve the conformity with international standards	**(L2T1)** Contribute in the development of standards on resilience guidelines and policies
LEADERSHIP & GOVERNANCE	**Learning culture (learning and dissemination) (L3)**	**(L3S1)** Develop a strategy to create a resilience culture	**(L3M1)** Promote a culture of resilience	**(L3A1)** Formalize the learning process and institutionalize regular debriefing meetings	**(L3R1)** Create a Learning city	**(L3T1)** Develop formal procedures to assess the effectiveness of the learning process
			(L3M2) Review of best practices to deal with shocks and stresses used in different sectors and other cities			**(L3T2)** Promote leadership for knowledge transferring and sharing among global cities, regions and nations
	Resilience plan development (L4)	**(L4S1)** Identify the city requirements regarding resilience process	**(L4M1)** Develop a resilience action plan to respond to shocks and long term stresses	**(L4A1)** Develop leading indicators for assessing the performance of the resilience action plan	**(L4R1)** Assess and monitor the efficiency of the resilience action plan periodically in order to improve it continuously	**(L4T1)** Share the CITY's expertise in resilience action plan development with other cities about to start the process

Table 9
Smart Mature Resilience Maturity Model: Preparedness dimension (Hernantes et al., 2019).

		STARTING	MODERATE	ADVANCED	ROBUST	VERTEBRATE
PREPAREDENESS	**Diagnosis and Assessment (P1)**	**(P1S1)** Assess and manage a wide range of risks **(P1S2)** List and prioritize critical services and assets **(P1S3)** List existing plans and response mechanisms and guidelines for shocks and stresses	**(P1M1)** Take account of interdependencies between risks when assessing and managing risk	**(P1A1)** Assess and prioritize risk scenarios and their implications through consideration of risk systematicity	**(P1R1)** Undertake regular and long-term risk assessment with a focus on risk systematicity	**(P1T1)** Assess the value added by CITY contributions to the resilience of other CITIES
PREPAREDENESS	**Education and Training (P2)**	**(P2S1)** Conduct training and arrange emergency drills with the emergency teams and CI providers **(P2S2)** Inform citizens to volunteering opportunities in the local community **(P2S3)** Develop a common understanding of the resilience approach among stakeholders	**(P2M1)** Conduct training and arrange emergency drills including volunteers	**(P2A1)** Provide training for citizens and public and private companies **(P2A2)** Conduct emergency drills at national level **(P2A3)** Develop education programs in schools about the resilience action plan **(P2A4)** Assess and refine the training programs	**(P2R1)** Establish a strong network of volunteers **(P2R2)** Conduct frequent joint training exercises between European cities	**(P2T1)** Develop training plans in cooperation with other CITIES. **(P2T2)** Develop training activities for other CITIES **(P2T3)** Support self-organization of the involved agents to improve the Resilience of the CITY

objectives of this sub-dimension. Therefore, policies that should be implemented at different stages to achieve these objectives are defined within this sub-dimension. The second sub-dimension defines the path towards how to involve the city in major city networks with the aim of becoming more resilient and a leading city in the resilience building process.

The purpose of this tool is to serve as support in the operationalization of resilience, giving a detailed prescription about the activities that should be carried out to increase the resilience level of any city. The SMR MM is a roadmap that defines the optimal and sequential steps that cities should follow in order to build resilience in the most effective manner. This tool has been developed in general for city stakeholders and more in particular for decision makers at the city level responsible for building city resilience. Through this maturity model the evolution of the resilience building process is illustrated: 1) in the starting stage, the cities are working in silos where each department is working on its own in disaster management. 2) In the moderate stage, the awareness level on the importance of building resilience as a whole starts to raise, integrating the efforts of all the city stakeholders. 3) In the advanced stage, the resilience strategy plan is developed were the main actions towards resilience are defined from a holistic point of view. 4) In the robust stage, the city starts to internationalize the resilience building process by involving relevant stakeholders outside the city boundaries and taking an active role in different international networks. Finally, 5) in the vertebrate stage, the city becomes a reference for all the European cities in relation to resilience and promotes a culture of continuous improvement based on the lessons learned and with the commitment and involvement of all the stakeholders. The last stage has been defined as an ideal stage since none of the cities has reached this stage so far. However, as cities start approaching this last stage, we will be able to define the policies in this stage and how they could evolve to improve further more concretely. This stage can evolve and change based on the cities' progress and context. It might also happen that a new stage would have to be defined as cities continue evolving.

The contribution of this research is explaining how a co-creation process with multi-disciplinary experts and that applied different research methods was performed with the aim of developing a comprehensive and detailed SMR MM, which provides support in the planning and decision-making process of the resilience-building process at a strategic level. Since the tool covers all the resilience dimensions, it illustrates from a holistic perspective the different actions that need to be implemented establishing a temporal order. Additionally, it is also helpful in justifying the funding needs and other specific measures.

The SMR MM can also be used as guideline to involve all relevant stakeholders in emergency preparedness and crisis management through plan preparation, regular training, emergency drills and exercises. Moreover, the SMR MM facilitates the diagnosis of the resilience level of any city by reviewing which policies included in the SMR MM have already been implemented and what maturity stage they belong to. Once the resilience level of the city is assessed, the SMR MM helps cities identify policies that are suitable for increasing their resilience level and also for prioritizing the order of implementation of the policies.

As a result of the pilot implementations, the three cities were positioned in the following maturity stages: Kristiansand was positioned in the Moderate stage, and already starting the implementation of the Advanced stage policies; Donostia-San Sebastian was positioned in the Moderate stage; and Glasgow was positioned in the Robust stage, although for the Cooperation and Leadership and Governance dimensions they could be positioned in the Vertebrate stage. Furthermore, each city was able to find its weakest points in the resilience-building process and the next policies that should be implemented in the future.

Table 10
Smart Mature Resilience Maturity Model: Infrastructure and Resources dimension (Hernantes et al., 2019).

		STARTING	MODERATE	ADVANCED	ROBUST	VERTEBRATE
INFRASTRUCTURE & RESOURCES	**Reliability of infrastructures (I1)**	**(I1S1)** Develop cooperation/ collaboration agreements with critical providers **(I1S2)** Develop plans to monitor CIs functionality **(I1S3)** Develop contingency plans for CIs	**(I1M1)** Identify interdependencies of critical services at local level **(I1M2)** Develop periodical preventive maintenance procedures for CIs **(I1M3)** Develop measures to increase CI redundancy and reliability **(I1M4)** Implement monitoring systems for identifying risk shocks and long term stresses **(I1M5)** Carry out audits for CI providers	**(I1A1)** Develop flexibility measures	**(I1R1)** Identify interdependencies of critical services at international level	**(I1T1)** Encourage the continuous improvement of policies, to take advantage of any shock and stress to bounce forward and improve or re-design **(I1T2)** Apply big data approaches to analyze the information obtained
INFRASTRUCTURE & RESOURCES	**Resources to build up resilience (I2)**	**(I2S1)** Assess current initiatives and funding opportunities for the development of resilience **(I2S2)** Develop a list of the currently available response physical resources **(I2S3)** Deploy a disaster relief fund for emergencies	**(I2M1)** Allow for the resilience action plan in the local government budget **(I2M2)** Promote resources /tool sharing among CI providers within a region during crises	**(I2A1)** Promote and provide incentives for initiatives that contribute to build resilience **(I2A2)** Implement centralized control of coordination of critical resources and activities during shocks and stresses. **(I2A3)** Encourage stakeholders to have appropriate insurance coverage **(I2A4)** Promote and provide incentives for the development of sustainable urban infrastructures	**(I2R1)** Promote and provide incentives to stakeholders for investment in R&D&I projects regarding Resilience. **(I2R2)** Monitor an effective use of resources to ensure the resilience-building process performance	**(I2T1)** Assess the impact of innovation in the resilience-building process. **(I2T2)** Monitor the insurance level of stakeholders

Table 11
Smart Mature Resilience Maturity Model: Cooperation dimension (Hernantes et al., 2019).

		STARTING	MODERATE	ADVANCED	ROBUST	VERTEBRATE
COOPERATION	**Development of partnerships with city stakeholders (C1)**	**(C1S1)** Map relevant stakeholders to develop the resilience action plan	**(C1M1)** Develop a stakeholder engagement plan defining its roles and responsibilities	**(C1A1)** Align the objectives of different stakeholders and develop a common understanding of resilience	**(C1R1)** Widen collaborative networks with stakeholders to reflect on and make decisions about the progress of the city resilience	**(C1T1)** Support self-organization of the cooperation among all the stakeholders involved in the resilience development
		(C1S2) Develop a public website with emergency information	**(C1M2)** Develop an internal communication platform for sharing information with different municipal departments and emergency services	**(C1A2)** Develop formal partnerships between academic and scientific entities to improve the resilience building process	**(C1R2)** Arrange multi-stakeholder debriefing meetings	**(C1T2)** Involve all stakeholders in the learning process
				(C1A3) Undertake public consultations to receive feedback on the resilience action plan	**(C1R3)** Develop a public platform to enhance learning among city stakeholders	
				(C1A4) Develop a public communication platform to interact with stakeholders		
COOPERATION	**Involvement in resilience networks of cities (C2)**		**(C2M1)** Establish alliances with cities facing similar risks	**(C2A1)** Join a major Network of EU cities	**(C2R1)** Participate proactively in regional, national and international networks to promote initiatives, exchange experiences and learn	**(C2T1)** Active involvement of local authority and stakeholders in networks (local, national, European & Global)
				(C2A2) Develop formal partnerships with regional stakeholders		**(C2T2)** Encourage stakeholders to present their experience concerning the resilience-building process as reference for other CITIES

6. Conclusions

This research takes a step forward in the process of building city resilience. Although several of the process attributes and characteristics can be found in the literature, there is still a need to provide cities with a detailed roadmap so they know how to operationalize the resilience-building process. The SMR MM developed in this research aims to meet these gaps and provide support to cities in assessing their resilience level and improving it.

The SMR MM defines five maturity stages that cities should go through in order to improve their resilience level. In turn, it defines a set of resilience policies that need to be implemented in order to fulfill the objectives of each maturity stage and move a step further from a holistic perspective. These policies have been classified according to the four resilience dimensions that emerge from the literature. This model has been developed over a co-creation process, which guarantees the integration of different perspectives and expertise. The participation of the experts in this process increases their confidence in the outcome.

Although this SMR MM provides a practical and useful tool for building the resilience level of cities, it has some limitations. The policies have been defined from a highly strategic level, and therefore when putting them into practice, it is necessary to customize them to each city context. In this respect, a closely related tool called a Portfolio of Resilience Building Policies[1] has been developed in the project. The aim of this tool is to define more operational policies by providing examples of how the strategic policies identified in the MM could be implemented in practice. Furthermore, the model does not define how much time each city will need to advance to a higher stage since this could vary from city to city as well as from stage to stage. It also depends on the amount of resources a city allocates to this resilience-building process as well as the city's commitment to resilience. As further implementations through follow up studies in different European cities are carried out, we will be able to ascertain the value of the SMR MM in supporting cities in the resilience building process as well as to define some guidelines when implementing it.

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