Building upon the existing knowledge: Updating and improving the Smart Mature Resilience Model

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ABSTRACT

In recent years the concept of urban resilience has acquired great relevance within urban planning. The complexity of urban systems and the wide scope of the resilience concept require tools to facilitate the integration of the concept in urban development. Numerous studies, tools, and theoretical frameworks have been developed to support the resilient transformation of cities. However, these initiatives are usually not holistically integrated and limit incorporating the changes and advances in the resilience concept. This article highlights the importance of shifting from a continuously-building-new approach to building on an existing knowledge approach. This study has updated and improved the maturity model developed within the Horizon 2020 project Smart Mature Resilience. A bibliometric analysis was carried out to study the developments in resilience over the past four years and to integrate the relevant advances in the area into a new version of the Smart Mature Resilience Maturity Model (SMR MM).

Keywords

Resilience dimensions, bibliometric analysis, urban resilience, framework

1. INTRODUCTION

The population growth and the consequent urbanization increase the exposure and vulnerability of urban areas to various risks and hazards affecting all city dimensions, including environmental, social and economic factors (Jabareen, 2013; Z. Liu, Xiu, & Ye, 2020). In response to these challenges, the concept of resilience has increasingly been recognized as an essential principle in urban development. Urban resilience focuses on developing the preventive and adaptive capacities for dealing with unexpected threats rather than managing known city's risk (Meerow, Newell, & Stults, 2016; Normandin, Therrien, Pelling, & Paterson, 2019). In this study we use the IPCC definition on resilience "capacity of social, economic, and environmental systems to cope with a hazardous event or trend or disturbance, responding or reorganizing in ways that maintain their essential function, identity, and structure, while also maintaining the capacity for adaptation, learning, and transformation (IPCC, 2014).

Urban systems are dynamically complex, governed by non-linear and dynamic relationships constantly changing over time (Rotmans, van Asselt, & Vellinga, 2000). Consequently, the process for increasing urban resilience should be addressed from a multi-dimensional and holistic point of view (Serre & Heinzlef, 2018). The wide scope of the concept and the complexity in developing methods to measure the city's resilience level requires a resilience framework that allows representing this complexity and, more importantly, incorporating the changes in the concept over time.

In this context, a Smart Mature Resilience Maturity Model (SMR MM) was developed by the Horizon 2020 project Smart Mature Resilience (SMR). The main aim of the SMR MM was to facilitate the operationalization

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of the city's resilience building process by defining paths that help cities prioritize resources and efforts to develop resilience (Hernantes et al., 2019).

However, the changes of resilience-related concepts and the feedback provided by the cities in adopting resilience strategies justify a revision and update of the original SMR MM.

This article presents an analysis of the developments in resilience over the past four years and describes the revisions they motivated in the initial SMR MM. Due to the complexity of the development process of the SMR MM, we believe building upon existing knowledge is preferable to building a new model from the beginning. The result is a new version of the SMR MM, which is the basis for an ongoing operationalization (J.H.Canos et al, 2022).

Although numerous studies, tools, and theoretical frameworks have been developed in the field of urban resilience (Arup, 2014; UNISDR, 2015; 100 Resilient cities, 2016; Cardoso et al., 2020; Wardekker et al., 2020; Word Bank Group, 2021), only part of these isolated initiatives have been holistically integrated. Instead of developing new resilience frameworks, we consider that improving, updating, and integrating the relevant advances in the area into a new version of the SMR MM is a more efficient approach to support the transformation of urban areas into a more resilient system. To complete the review and update the SMR MM, a bibliometric analysis combined with a semi-structured literature review was carried out to study the developments in resilience over the past four years and integrate the relevant advances in the area into a new version of the SMR MM. Therefore, the main research questions are: a) which elements were not sufficiently considered in the first version of the SMR MM?; b) is the bibliometric analysis a feasible tool to identify gaps in the resilience field and, thus, opportunities for improving the SMR MM?The remaining of this article will cover the background information about the SMR MM (Section 2) and a description of the methodology adopted to perform the SMR MM update (Section3). Section 4 describes the advances we found in the resilience concept and how they were incorporated in the new version of the SMR MM. In Section 5, we discuss the benefits brought by the changes introduced and their effects on the operationalization process. Finally, Section 6 concludes the paper.

2. BACKGROUND

The SMR MMis designed as an easy-to-use tool for assessing and improving cities' preparedness, response, and recovery when known or unknown risks or hazards occurs (Iturriza et al., 2019; Labaka et al., 2019). This tool is intended to be used by the city's decision-makers responsible for building resilience. The SMR MM was developed as a roadmap that includes a sequence of maturity stages for cities that facilitates the self-assessment of the city's resilience level. Each maturity stage includes policies designed to enhance and develop the overall resilience level by moving from one stage to the next. The SMR MM was developed through a co-creation process in which 40 experts with different background and from diverse cities in Europe took part (Hernantes et al., 2019). The SMR MM defines five sequential maturity stages (Starting, Moderate, Advanced, Robust and Vertebrate) that the city should go through in order to develop resilience. Each stage is characterized by a set of objectives, involved stakeholders and a list of policies that should be implemented to achieve the states' objectives. These policies are classified into four dimensions (leadership and governance, preparedness, infrastructures and resources, and cooperation). At the same time, each dimension has been divided into sub-dimensions that group sets of policies. The leadership and governance dimension comprise four sub-dimensions (Cross-sectorial and multi-governance collaboration, L1; Legislation development and refinement, L2; Learning and dissemination, L3 and Resilience action plan development, L4). The preparedness dimension contains policies to improve the diagnosis and assessment of the city resilience level and policies to engage and train stakeholders to deal with disasters. This dimension comprises two sub-dimensions (Diagnosis and Assessment, P1 and Education and Capacity building, P2). To develop the resilience action plan, a series of policies to achieve higher levels of robustness, redundancy, resourcefulness, and rapidity in the face of a disaster are grouped into two sub-dimensions (Infrastructures and essential services I1 and resources to build up resilience I2). Finally, the cooperation dimension is divided into two sub-dimensions (Collective engagement and awareness, C1 and Involvement in resilience networks of cities, C2). Both sub-dimensions include policies seeking for the partnership between city stakeholders as well as alliances with other cities. Figure 1 represents a graphical description of the SMR MM structure. A detailed description of the model and the process at which it was created can be found in (http://smr-project.eu/).

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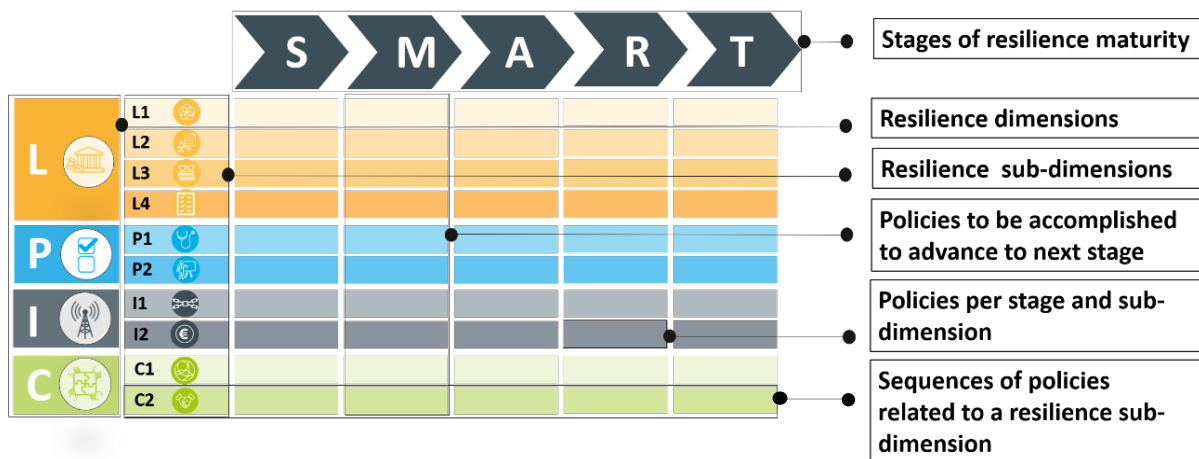
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Figure 1. Showing initial SMR MM structure. On the horizontal axis maturity stages: Starting, Moderate, Advanced, Robust and Vertebrate. On the vertical axis are found resilience dimensions: Leadership and governance, Preparedness, Infrastructure & Resources and Cooperation

3. METHODOLOGY

This study undertook a two-tier analysis combining semi-structured literature review and bibliometric analysis to examine two aspects of the SMR MM: its policies and resilience dimensions (see figure 2). Firstly, the dimensions proposed in 2016 were reviewed and compared with the most recent publications and frameworks on resilience. The intention was to identify resilience dimensions that were not already included in the SMR MM and that could potentially improve the operationalization and usefulness of the SMR MM if included. Secondly, a complete revision of resilience policies proposed by other resilience frameworks was reviewed to improve and develop a more complete SMR MM. In a first step, the bibliometric analysis was used to make the first quantitative analysis of the scientific works on the concept of resilience applied to cities. The objective of this analysis was to study the development of the resilience approach in the last five years in order to identify aspects that were not considered in the development of the SMR MM (i.e. resilience dimensions). In a second step, the literature review was used to validate the bibliometric analysis's conclusions and identify resilience policies.
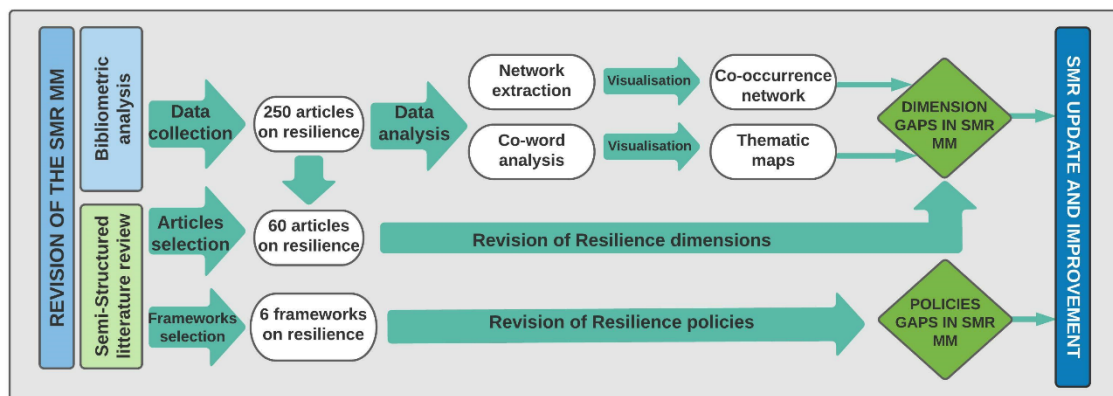

Figure 2. Flowchart diagram showing the methodological process

3.1. Bibliometric analysis

Bibliometric analysis facilitates the examination of past and future growth of the literature of a given domain by statistically analysing scholarly documents (Aria, Misuraca, & Spano, 2020; Cobo et al., 2011). Quantitative methods to map science structure are a useful tool for research planning. For instance, co-word analysis has been widely used within the bibliometric techniques to identify the main themes within a discipline or research area (He, 1999). This approach offers the possibility of detecting linkages among research areas that otherwise may be difficult to reveal. It also facilitates the description of the dynamic evolution of a research study (Kostoff, 1993). This study uses this analytical method to examine large volumes of documentation related to the resilience concept to map its trend and research direction over time and the main research fields at which the concept of resilience is

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being applied. We have combined bibliometric analyses such as co-occurrence analysis or keywords co-occurrence networks to reveal the most relevant resilience dimensions from the existing resilience frameworks. The purpose of combining different analyses was to investigate the aspects of the scientific work related to resilience and to identify gaps in the defined resilience dimensions and policies in the first version of the SMR MM.

In this study, the Bibliometrix-R package (http://www.bibliometrix.org) was used to perform a comprehensive science mapping analysis of the recent (5 years) scientific literature on resilience. This open-source platform provides a set of tools to execute quantitative research in bibliometrics (Aria & Cuccurullo, 2017). After defining the research objective (reviewing and updating the SMR MM), the bibliometric analysis was carried out in three steps: 1) Data collection, 2) data analysis, and 3) data visualisation and interpretation.

3.1.1 Data collection

In this study, Scopus (http://www.scopus.com) was used to collect and screen peer-reviewed journal articles. We employed strings of keywords ("Urban" AND "Resilience" AND "Resilient" AND "Framework") to search relevant studies on resilience. We also filtered all those research works not written in English and only analysed studies from the past five years. A total of 250 articles were analysed. The metadata stored in Scopus was converted into a suitable format to be analysed and processed by the bibliometrix-R package. To ensure the reliability of the data a process to delete duplications was carried out.

3.1.2 Data analysis

Scientific journals and authors assign keywords (concepts with high relevance to their research topic) to the different scientific publications or research works. The bibliometric analysis uses these keywords as units of analysis. In this research, the tools provided by the Bibliometrix package were used to extract a co-occurrence network and perform a co-word analysis from the title, keywords and abstract. The main principle of the co-word analysis is that the proximity of pairs of words in a document (e.g. words from abstracts) is used to identify relationships within the subject areas presented in the texts (Kostoff, 1993). To facilitate the visualisation and analysis of the results, the interconnections are represented in a co-occurrence network. The strength of the relationships composing the network is defined by criteria such as the inclusion index (Rip & Courtial, 1984) and the proximity index (Peters & van Raan, 1993) used to cluster different elements of the network map into groups.

The analysis of the networks was used to a) characterise the main resilience topics, b) reveal the conceptual structure and c) map the thematics of the resilience domain. As a result, we obtained a description of the main topics covered by the studied journals, in addition to understanding the thematic evolution of the resilience concept and identifying important themes that were not considered in the first version of the SMR MM.

3.1.3 Data visualisation and interpretation

In this stage of the bibliometric analysis, intuitive visualisation tools from the Bibliometrix package were used to map and represent the scientific structure of the resilience field. More specifically, co-occurrence networks and thematic maps were used to visualise the trends in the field of resilience (See figure 3 and 4 from the results section). Co-occurrence networks represented the frequency at which pairs of words appeared simultaneously in the abstract, title or keyword, facilitating the identification of themes usually studied together in resilience research. In the network, each theme is represented by a node connected with other nodes with an edge or link representing their co-occurrence (proximity in a text). At the same time, clusters of nodes (themes) with high proximity between them are grouped into clusters (Liu & Mei, 2016). The node´s impact level in the networks is represented by its size and is dependent on the theme´s frequency and the number of connexions with other nodes. The thickness of the link represents the strength of the relationships between nodes.

The thematic map was used to plot themes according to their centrality (importance of a node within a graph defined by the number of links of a node) and density rank (proportion of direct links in the network relative to the total number possible). Each theme or cluster was represented in a two-dimension space that allowed for classifying the themes into four groups: lower-right quadrant: basic themes; lower-left quadrant: emerging or disappearing themes; upper-left quadrant: very specialised/niche themes and upper-right quadrant: motor themes.

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3.2. Literature review

The interpretation and complete analysis of the bibliometric results was carried out with a semi-systemic literature review performed in two phases. In the first phase, 60 out of the 250 articles used for the bibliometric study were selected for extensive reading. The 60 articles were chosen based on whether the study proposes or defines a resilience framework that includes resilience dimensions and policies, indicators or actions for its development or assessment. The main objective was to understand how the different studies understood the concept of resilience and recognise different dimensions to be covered by the term resilience. The dimensions mentioned in each study were numbered to identify dimensions that were not considered in the SMR MM. Once the dimensions mentioned in each scientific work were identified, we conducted a homogenisation process since many of the dimensions differed in the term used but not in its meaning. The dimensions described in the SMR MM were taken as a reference in the homogenisation process.

After the litteratura review, we selected five resilience frameworks based on the level of details they provide as well as for their recognition and popularity in building resilience (see table 1). Taking these frameworks as a basis, the main objective was to identify policies that had not been described in the SMR MM to improve and facilitate its operationalisation.

Table 1. Resilience frameworks selected for extensive reading.

Framework	Focus	Reference
Resilience assessment framework (RAF)	Climate Change	(Cardoso et al., 2020)
City Resilience Framework	City resilience	(ARUP, 2014)
A diagnostic tool for supporting policymaking on urban resilience	Policy making support	(Wardekker et al., 2020)
Disaster Resilience Scorecard	Disaster resilience in local governance	(UNDRR, 2017)
UN-Habitat Resilience	Participatory resilience planning methodology	(UN-Habitat, 2018)

43. RESULTS

In this section, first, the results obtained from the bibliometric analysis will be presented. Then, the findings from the literature review analysis will update and improve the maturity model developed within the Horizon 2020 project Smart Mature Resilience.

4.1 Results from the bibliometrics analysis

The results of the co-occurrence network show four clusters represented with different colours centred around

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four core themes or disciplines, respectively (see figure 3). The core themes (node with more substantial
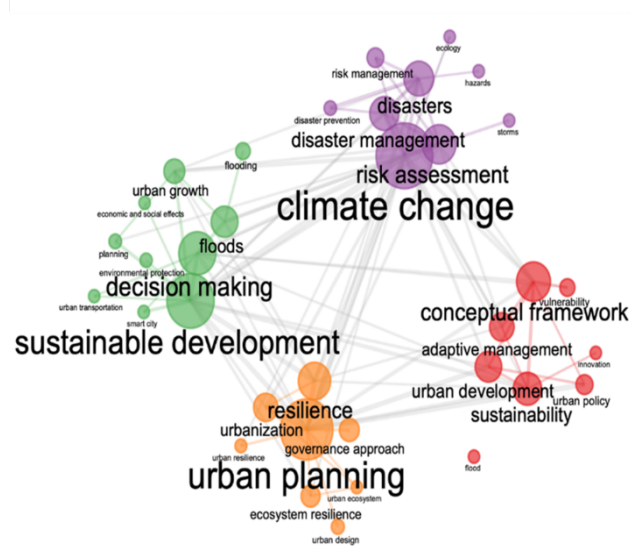

Figure 3. Co-occurrence network

influence) for each cluster are climate change (in purple), sustainable development (in green), urban planning (in orange) and conceptual framework (in red). The results of the thematic map support the conclusions of the network (see figure 4). Climate change, sustainable development and urban planning appear again as influential clusters of the map. Additionally, the map shows the importance of other terms such as ecosystems resilience or environmental protection. A total of six clusters are represented on the map. The terms ecosystem resilience, urban design and flooding are represented in the same cluster, located in the upper-right quadrant. These themes are characterized by high centrality and high density, meaning well-developed themes with high importance for the resilience field (motor themes).

Two clusters are located in the lower-right quadrant. The first cluster is composed of urban planning, urban area and conceptual framework, showing that these words frequently appear together in the same research work. The second cluster contains the words climate change, sustainable development and resilience. These two clusters are characterized as transversal themes with high centrality but with low density, demonstrating the importance of the themes in the resilience field despite their lack of development.
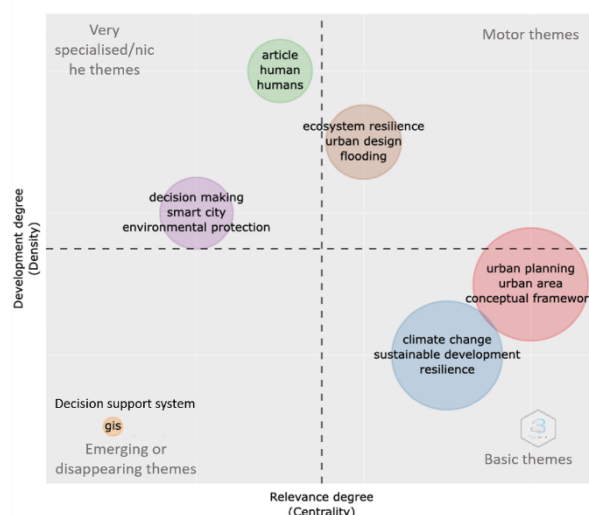

Figure 4. Thematic map

The terms GIS and decision support systems are represented as declining themes within the lower-left quadrant, with low centrality and low density. This shows that these themes are not well developed in the resilience field

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and are only mentioned in a small number of studies.

Finally, two clusters are located in the upper-left quadrant, with high density (well-developed internal links) but low centrality (unimportant or irrelevant external links). The first cluster (human, humans and article) lacks importance for the analysis and conclusions of this study since it is composed of words frequently used in scientific articles, regardless of the discipline. The second cluster contains the terms smart city, decision making and environmental protection. This cluster is considered to be highly developed but isolated from the other clusters of the map. The analysis of the co-occurrence network and the thematic map stress the importance of the environmental dimension in the resilience field as well as the strong influence of the themes of urban planning and urban development. The strong relationship these terms show with climate change in the co-occurrence network and the fact that both terms were characterized as transversal themes (high degree of centrality in the resilience studies) in the thematic map show the need to consider them jointly in the same dimension. For this reason, we decided to include the dimension of landscape and urban planning within the SMR MM. We divide this dimension into two sub-dimensions, urban planning and environmental. The intention was to represent in the same dimension all policies aiming to improve environmental resilience, resilience towards climate change impacts, and policies that promote sustainable and resilient urban development.

4.2 Results from the Literature review analysis

The results of the first phase of the literature review are reported in Tables 2 and 3. A total of 60 articles were selected for an exhaustive reading to analyse the resilience dimensions. From these 60 articles, 20 articles mentioned resilience dimensions. Most of the studies differed in terms of referring to the same dimension. Table 2 shows the dimensions mentioned in each of the 20 articles describing different aspects or dimensions of resilience. Furthermore, the table associates these dimensions with those defined by the SMR MM. As shown in table 2, many studies identified social or social resilience as an essential dimension in resilience. The characteristics and objectives described for this dimension are reflected in the SMR 'preparedness' and 'cooperation' dimensions. These two dimensions focus on improving society's preparation for risk, including the one from vulnerable groups and the cooperation between different stakeholders. As shown in table 2, 14 articles out of 20 mentioned dimensions that correspond to the 'leadership and governance' SMR dimension. 17 papers mentioned dimensions that can be associated with 'infrastructure and resources'; 16 mentioned dimensions associated with 'preparedness 'and, 14 papers with 'cooperation' SMR MM dimensions. Only four articles mentioned dimensions that could not be associated with any of the elements described in the SMR MM. Besides, none of these dimensions was repeated or mentioned in any of the other articles, being mentioned in isolation on one scientific journal. Therefore, they were not considered relevant for our study.

Finally, the analysis results show the importance of considering the environmental aspect when defining and assessing the city's resilience. The 'environmental' dimension was mentioned in 17 of the 20 articles that described resilience dimensions (see table 2). This, together with the bibliometric analysis results, reflects the need to include a new dimension of the SMR MM that describes specific policies to face climate change and the degradation of ecosystems.

Once the need to include a new dimension was identified, we reviewed six of the most important resilience frameworks in depth. This process's main objective was to identify new policies that could improve and facilitate the implementation of the SMR MM for resilience policy-making. Two types of policies were included in the new version of the SMR MM: new policies not included in any dimension or maturity stage of the model, and policies that helped showing the maturity development of an already-included policy. A total of new 27 policies were identified and included in the new version of the SMR MM (see table 3). 15 of the 27 policies were not previously considered in the SMR MM, whereas 12 out of 27 were included to facilitate the development of existing policies across the maturity stages. The updated version of the SMR MM can be found in annex A. Although the maturity stage of each policy has not been validated by experts, we have suggested the maturity stage at which the policy could be included. The suggestion has been based on our expertise in the field of urban resilience and on our past experience developing the SMR MM.

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Table 2. Showing the dimensions mentioned in each scientific work and the dimension used by the SMR MM to which it corresponds.

Leadership and governance	Infrastructure and resources	Preparedness	Cooperation	Environmental	Other dimensions	Research article
	Organizational Functional			Spatial Physical		(Cardoso et al., 2020)
Leadership & strategy	Economy & Society	Health & Wellbeing		Urban systems & services		(Montella & Tonelli, 2018)
					Exante component Disturbance component Expost component Local components	(Tanner, Bahadur, & Moench, 2017)
Organization		Knowledge	People	Place		(ARUP, 2014)
	Functional	Social equity		Species diversity	Temporal spatial	(Bush & Doyon, 2019)
Governance	Economy, Infrastructure	Society	Society			(Feldmeyer et al., 2019)
Institutional	Economic, Infrastructure	Social, Information/Comm unicati-on	Social Information/Comm unication	Environmental		(Cutter, 2016)
	Infrastructure	Quality of life	Equity and social inclusion	Environmental sustainability	Productivity	(Schlör, Venghaus, & Hake, 2018)
Institutional resilience	Economic	Social resilience, Community capital	Social resilience	Environmental resilience		(Cutter, Ash, & Emrich, 2014)
Institutional	Physical, Economic	Social	Social	Natural		(Ribeiro & Gonçalves, 2019)
Institutional	Physical, Economic	Social	Social	Natural		(Shaw & Team, 2009)
Governance and institution	Infrastructure	Social and economic,		Environmental and climate change		(Almutairi, Mourshed, & Ameen, 2020)

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Leadership and governance	Infrastructure and resources	Preparedness	Cooperation	Environmental	Other dimensions	Research article
Institutional	Economic, Infrastructure	Community	Community	Environmental		(Cai et al., 2018)
Institutional	Economic, Infrastructure	Social resilience, Community capital	Social resilience, Community capital	Environmental		(Chen, Huang, Li, & Luna-Reyes, 2019)
Politics and governance	Infrastructure and services, Economy and Livelihoods	Social and cultural dimensions	Social and cultural dimensions	Space and settlements		(Patel, Sanderson, Sitko, & De Boer, 2020)
Organisational	Functional, Physical			Spatial		(Cardoso et al., 2020)
Governance and stakeholders' involvement	Economic Sustainability Service Management Infrastructure safety and Robustness Infrastructure Preparedness	Social Involvement and co-benefits, Infrastructure Preparedness	Governance and stakeholders' Involvement Resilience engaged service	Environmental resilience Spatial planning		(Beceiro, Brito, & Galvão, 2020)
	Technical resilience	Social resilience	Social resilience	Urban resilience		(Serre & Heinzlef, 2018)
			Social cohesion Diversity		Innovation Tightness of feedbacks Modularity	(Suárez, Gómez-Baggethun, Benayas, & Tilbury, 2016)
political peripheral	Economic	Social	Social	Environmental		(Bates, Angeon, & Ainouche, 2014)

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Table 3. Showing 27 policies included in the new version of the SMR MM.

Sub-dimensions	Policy	REASON FOR INCLUSION		REF
		Was not included in SMR	To show the maturity development	
Municipality, cross-sectorial and multi-governance collaboration	Implement the multi-level governance approach to establish an organisational structure with strong leadership and clarity of coordination between municipal, regional and national levels of governance.		X	(UNDRR, 2017)
Legislation development and refinement	Integrate resilience approach into existing risk reduction and prevention policies by establishing new strategies, acts, laws and codes.	X		(UNDRR, 2017)
	Develop disaster management, response and recovery plan.	X		(UNDRR, 2017)
Resilience action plan development	Adopt a bottom-up approach that facilitates transparent and inclusive participatory and multi-stakeholder consultation processes to develop resilience planning, policies and strategies	X		(ARUP, 2014; UNDRR, 2017)
	Integrate climate change perspective in developing the resilience action plan by incorporating climate risk information at every phase of policy planning.	X		(Cardoso et al., 2020; UNDRR, 2017)
	Properly integrate the resilience strategy with other key city functions (planning, sustainability, emergency management, infrastructure management)	X		(Cardoso et al., 2020; UNDRR, 2017)
Diagnosis and Assessment	Develop and install effective systems to detect and monitor potential hazards and assess risk		X	(ARUP, 2014; UNDRR, 2017)
	Develop effective associated communication systems to alert about potential risks		X	(UNDRR, 2017)

The leftmost column spans: **Leadership & Governance** (first six policy rows) and **Preparedness** (last two policy rows).

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	Education and Training/Capacity building	Develop awareness campaigns to the most vulnerable and at need populations in the city	X	(UNDRR, 2017)
Infrastructure & Resources	Infrastructures and essential services	Establish a critical infrastructure overview plan or strategy to protect the city´s critical infrastructures, utilities and services.	X	(Cardoso et al., 2020; UNDRR, 2017)
		Design and implement measures and strategies focused on preparing the business for adverse events.	X	(UNDRR, 2017; Wardekker et al., 2020)
		Establish comprehensive, resourceful and flexible business continuity planning across public and private sectors.	X	(ARUP, 2014)
		Define regulations, codes and standards appropriate to local context and risk profiles to guarantee business continuity and protective plans.	X	(ARUP, 2014)
	Resources to build up resilience	Assess current initiatives and funding opportunities for the development of resilience.	X	(UNDRR, 2017)
		Establish inclusive and resourceful finance mechanisms to enable businesses to adapt to changing circumstances and put in place contingencies for shock events.	X	(ARUP, 2014; UNDRR, 2017)
Cooperation	Collective engagement and awareness	Implement an inclusive and transparent mechanism to engage and communicate with governmental groups and citizens, aiming to improve cooperation between them.	X	(ARUP, 2014)
		Integrate community organisations in pre-event planning and post-event response for each neighbourhood in the city by establishing networks and training.	X	(Cardoso et al., 2020; UNDRR, 2017)

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		Conduct regular monitoring and analysis of relevant data to inform city planning and strategies.	X	(ARUP, 2014; UNDRR, 2017)
		Develop cohesive social structures to provide support at individual, household and local community level.	X	(ARUP, 2014)
Landscape and urban planning	Urban development	Update building regulations and standards regularly to consider new or changing risk-related data and evidence.	X	(UNDRR, 2017)
		Incorporate sustainable design principles and risk-aware planning approaches to design and implement new buildings, neighbourhoods, and infrastructures.	X	(UNDRR, 2017)
		Integrate green and blue infrastructures into city policy to maximise the use of urban design solutions.	X	(Cardoso et al., 2020; UNDRR, 2017)
		Develop guidelines to integrate resilience concepts in urban planning by various practitioners.	X	(UNDRR, 2017)
	Environmental	Promote awareness and provide information in the role that ecosystems and their associated ecosystem services may play in the city´s disaster resilience.	X	(Cardoso et al., 2020; UNDRR, 2017)
		Identify critical ecosystem assets outside the city boundary that helps to enhance city resilience.	X	(UNDRR, 2017)
		Adopt climate change prevention actions such as Nature Based Solutions (NBS).	X	(Cardoso et al., 2020; UNDRR, 2017)
		Promote and establish transboundary agreements and collaborations to support the protection and management of transboundary ecosystems.	X	(UNDRR, 2017)

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5. DISCUSSION

In recent years, the concept of resilience has acquired great relevance within the political spheres. Consequently, a large number of studies, tools and theoretical frameworks have been developed to promote the resilient transformation of cities. However, only a small portion of these resources have been holistically integrated. In this study, we want to highlight the need to shift towards building upon the existing knowledge approach; instead of continuously building new resources, we update, improve and build on those existing tools and approaches that have proven to facilitate the resilience-building process. In this way, instead of generating new knowledge used by a small number of users, we generate standardised knowledge and resources oriented to end-users and policy-makers. Considering this, we have reviewed, updated and improved the maturity model developed within the Horizon 2020 project Smart Mature Resilience. For this, we have carried out a bibliometric analysis combined with a semi-structured literature review to identify potential gaps, or in other words, opportunities for improving the model. We used co-occurrence networks and thematic maps to visualise and identify relevant aspects of the resilience field that were not previously considered in the first version of the (SMR MM). The analysis results stressed the importance of the environmental dimension in the resilience field. They also showed the strong influence of urban planning and urban development themes and the tight relationship between these concepts with climate change. The results mean climate change is relevant in urban planning and development. Therefore, we included the 'landscape and urban planning' dimension within the SMR MM. composed of two sub-dimensions, urban planning and environmental. The intention was to represent in the same dimension all policies aiming to improve environmental resilience, resilience towards climate change impacts, and policies that promote sustainable and resilient urban development. The exhaustive reviewing process carried out in this study allowed us to identify 27 policies that were not previously considered within the SRM MM. We believe the update of the model with these new policies improves the operationalisation and functionality of the SMR MM. The use of bibliometric indicators combined with a semi-structured literature review has provided a series of advantages for updating and improving the SMR MM. Firstly, bibliometric analysis is an easy-to-use method that is objective, verifiable and easy to reproduce; additionally, visualisation tools provided by the Bibliometrix package facilitated the analysis of large volumes of data. Secondly, identifying gaps and relevant aspects in the field of resilience facilitated identifying suitable policies for the complete operationalisation of the SMR MM. Bibliometric analysis offers opportunities beyond the field of resilience. It is an easy and quick tool that allows obtaining reliable indicators related to quality and research impact.

Despite the advantages mentioned above, the methods used have also presented limitations that should be considered when interpreting the results. For example, the bibliometric analysis is limited to scientific publications, excluding other sources of information such as government reports, websites or platforms on resilience that are not indexed in the Scopus database. Nevertheless, many resilience-building measures are described in these types of information resources. Additionally, the quality of the co-word analysis carried out in this study depends on various factors, such as the quality of keywords and index terms, the scope of the Scopus database, and the simplification process carried out to represent findings. The keywords we used to select the articles from the Scopus database may have biased the results of the co-word analysis. For example, the great influence of the term 'conceptual framework' or 'urban planning' on the network could be because some of the keywords used to collect and screen peer-reviewed journal articles were urban and framework (see section 3.1.1). This effect could have also affected the results of the thematic map where one of the clusters located in the lower-right area contains the themes urban planning, urban area and conceptual framework.

To overcome these limitations and complete the review and update of the model, we suggest an expert group validation through a Delphi process. This approach would also allow defining the maturity stage of each of the identified policies. To complete the operationalisation of the model it is necessary to test the models's effectiveness with end-users. We believe that the interaction between scientific knowledge providers and resilience-building tools users is crucial. Identifying effective ways to co-design and co-generate resilience-building tools with end-users (i.e. policy-makers, authorities, civil society) is needed to support the resilient transformation of socio-environmental systems.

6. CONCLUSIONS

Reviewing and updating existing tools and resources may be a practical approach to support the resilient transformation of cities. Holistically integrating different resources and improving the already developed tools with new knowledge may be more efficient and constructive than continuously generating resources that are not being fully used. In this article, we wanted to emphasise the importance of adopting this approach by updating and improving the maturity model developed within the Horizon 2020 project Smart Mature Resilience. Low demanding methods such as bibliometric analysis can be easily used to identify gaps in knowledge and opportunities for improvement. Understanding the structure of the resilience research work and reviewing the

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discipline's scientific evolution allowed us to identify the themes most frequently used in urban resilience research. When analysing the results, we observe that urban planning, sustainable development, climate change, or risk assessment strongly influences the resilience discipline. Despite not having carried out a validation process with an expert group, we have emphasised the need to include end-users in generating new knowledge, tools and resources. This way, end-users complete use of resilience-building tools and resources will be achieved.

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ANNEX A

Table A.1. Updated version of the SMR MM. Highlighted in green the added policies, in white the policies validated by experts from the first version of the SMR MM.

Subdimensions	STARTING	MODERATE	ADVANCED	ROBUST	VERTEBRATE
Municipality, cross-sectorial and multi-governance collaboration (L1)	(L1S1) Establish a working team responsible for resilience issues in the city.	(L1M1) Establish a single point of coordination in the city (i.e. resilience department or committee) that facilitates cross-departmental coordination board and procedures.	(L1A1) Implement the multi-level governance approach to establish an organisational structure with strong leadership and clarity of coordination between municipal, regional and national levels of governance.	(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) Align, integrate and connect the resilience action plan with national plans.		
		(L1M3) Promote equality of access to services and basic infrastructure to vulnerable sector of society.			
Legislation development and refinement (L2)		(L2M1) Integrate resilience approach into existing risk reduction and prevention policies by establishing new strategies, acts, laws and codes.	(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

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Learning culture (learning and dissemination) (L3)	(L3S1) Develop a strategy to create a resilience culture	(L3M1) Promote a culture of resilience among citizens, institutions and organisations by investing and promoting social and institutional cohesion. (L3M2) Establish a systemic approach to review existing strategies, practices, and actions to deal with shocks and stresses in different sectors and cities to capture lessons from past events and feed these lessons into the design and delivery of rebuilding projects.	(L3A1) Formalize the learning process and institutionalize regular debriefing meetings.	(L3R1) Create a ´Learning City ʻby establishing active networks with peer cities, industry groups, national resilience, and emergency management forums to exchange lessons learned and knowledge	(L3T1) Develop formal procedures to assess the effectiveness of the learning process
Resilience action plan development (L4)	(L4S1) Identify the requirements needed to boost the process of integrating the resilience approach into development policies. (L4S2) Develop disaster management, response and recovery plan.	(L4M1) Develop a resilience action plan to respond to shocks and long-term stresses by taking as a starting point those city elements and resources already available. (L4M2) Adopt a bottom-up approach that facilitates transparent and inclusive participatory and multi-stakeholder consultation processes to develop resilience planning, policies and strategies. (L4M3) Integrate climate change perspective in developing the resilience action plan by incorporating climate risk information at every phase of policy planning.	(L4A1) Develop leading indicators for assessing the performance of the resilience action plan. (L4A2) Properly integrate the resilience strategy with other key city functions (planning, sustainability, emergency managt, infrastructure mngt).	(L4R1) Perform periodic monitoring and assessment of the resilience action plan effectiveness to continuously update and improve the plan with new data and planning strategies.	(L4T1) Share the CITY's expertise in resilience action plan development with other cities about to start the process

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Diagnosis and Assessment (P1)	(P1S1) Identify and assess a full range of risks	(P1M1) Analyse the interdependencies when assessing and managing risk.	(P1A1) Assess scenarios of shocks and their cascading effects	(P1R1) Undertake regular and long-term risk assessment using risk systemic tools.	(P1T1) Assess the value added by CITY contributions to the resilience of other CITIES
	(P1S2) List existing plans and response mechanisms guidelines for shocks and stresses	(P1M2) Develop and install effective systems to detect and monitor potential hazards and assess risk	(P1A2) Develop effective associated communication systems to alert about potential risks.		
Education and Training/Capacity building (P2)	(P2S1) Conduct training and arrange emergency drills with the emergency teams and Critical Infrastructures providers	(P2M1) Conduct training and arrange emergency drills including volunteers	(P2A1) Provide training for citizens and public and private companies	(P2R1) Establish a strong network of volunteers	(P2T1) Develop training plans in cooperation with other CITIES.
	(P2S2) Inform citizens to volunteering opportunities in the local community	(P2M2) Develop awareness campaigns to the most vulnerable and at need populations in the city	(P2A2) Conduct emergency drills at national level	(P2R2) Ensure interoperability of emergency response systems in adjacent cities or countries by conducting frequent joint training exercises between European cities	(P2T2) Develop training activities for other CITIES
	(P2S3) Develop a common understanding of the resilience approach among stakeholders		(P2A3) Education programmes and campaigns for the general public (children, adults, private sectors, NGOs, volunteers...)		(P2T3) Support self-organisation of the involved agents to improve the Resilience of the CITY.
			(P2A4) Assess and refine the training programs		
Infrastructures and essential services (I1)	(I1S1) List and prioritize critical services and assets	(I1M1) Identify interdependencies of critical services at local level to avoid/reduce/limit cascading effects.	(I1A1) Develop flexibility and adaptive measures in CIs to manage unexpected events.	(I1R1) Identify interdependencies of critical services at international level	(I1T1) Encourage the continuous improvement of policies, to take advantage of any

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				shock and stress to bounce forward and improve or re-design.
(I1S2) Establish a critical infrastructure overview plan or strategy to protect the city´s critical infrastructures, utilities and services.	(I1M2) Conduct robust monitoring and preventive maintenance and renewal of critical infrastructures, with effective contingency planning.	(I1A2) Establish comprehensive, resourceful and flexible business continuity planning across public and private sectors.		(I1T2) Apply AI methods to analyse the information obtained.
(I1S3) Develop cooperation/collaboration agreements with critical providers to monitor their functionality	(I1M3) Develop measures to increase critical infrastructure redundancy and reliability by ensuring that best practices and updated risk information is used for asset design and management.	(I1A3) Define regulations, codes and standards appropriate to local context and risk profiles to guarantee business continuity and protective plans.		
(I1S4) Develop contingency plans for critical infrastructures	(I1M4) Implement monitoring systems for identifying risk shocks and long-term stresses on CIs			
	(I1M5) Carry out audits for critical infrastructure providers			
	(I1M6) Design and implement measures and strategies focused on preparing the business for adverse events			
Resources to build up resilience (I2) (I2S1) Assess current initiatives and funding opportunities for the development of resilience.	(I2M1) Allow for the resilience action plan in the local government budget	(I2A1) Promote and provide incentives for initiatives that contribute to build resilience and develop sustainable urban infrastructures.	(I2R1) Promote and provide incentives to stakeholders for investment in R&D&I projects regarding resilience.	(I2T1) Assess the impact of innovation in the resilience building process.

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	(I2S2) Assess the currently available response physical resources	(I2M2) Promote resources /tool sharing among CI providers within a region during crises.	(I2A2) Implement centralised control of coordination of critical resources and activities during shocks and stresses.	(I2R2) Monitor an effective use of resources to ensure the resilience building process performance	(I2T2) Monitor the insurance level of stakeholders
			(I2A3) Encourage the uptake of appropriate insurance products across all sectors and services.		
			(I2A4) Establish inclusive and resourceful finance mechanisms to enable businesses to adapt to changing circumstances and put in place contingencies for shock events		
			(I2A5) Integrate insurance companies and private sectors in the funding mechanisms of emergencies and post-disaster recovery actions		
Collective engagement and awareness (C1)		(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
		(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

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(I2S3) Deploy a disaster relief fund for emergencies and post-disaster recovery	(C1M3) Identify vulnerable groups of people and promote the engagement of those groups in the development of risk mitigation strategies	(C1A3) Undertake transparent and inclusive public consultation processes to improve and develop the resilience action plan	(C1R3) Develop a public platform to enhance learning among city stakeholders.
	(CIM4) Implement an inclusive and transparent mechanism to engage and communicate with governmental groups and citizens, aiming to improve cooperation between them	(C1A4) Develop a public communication platform to interact with stakeholders	
	(CIM5) Integrate community organisations in pre-event planning and post-event response for each neighbourhood in the city by establishing networks and training	(C1A5) conduct regular monitoring and analysis of relevant data to inform city planning and strategies	
		(C1A6) Develop cohesive social structures to provide support at individual, household and local community level.	

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 (e.g. city to city learning programmes, climate change, resilience initiatives etc.)	(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

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other CITIES

Urban development (U1)	(U1S1) Ensure the provision of climate information (so-called climate services) to assist decision-making.	(U1M1) Assess potential NBS that could potentially increase urban resilience (i.e. reducing climate change adverse events) and conduct an exhaustive evaluation of the potential co-benefit and disservices of these NBS	(U1A1) Integrate green and blue infrastructures into city policy to maximise the use of urban design solutions.
		(U1M2) Update building regulations and standards regularly to consider new or changing risk-related data and evidence.	(U1A2) Develop guidelines to integrate resilience concepts in urban planning by various practitioners.
		(U1M3) Incorporate sustainable design principles and risk-aware planning approaches to design and implement new buildings, neighbourhoods, and infrastructures.	
Environmental (U2)	(U2S1) Develop an ecosystem services assessment to quantify the ecosystems capacity to deliver ecosystem services over time.	(U2M1) Promote awareness and provide information in the role that ecosystems and their associated ecosystem services may play in the city´s disaster resilience.	(U2A1) Identify critical ecosystem assets outside the city boundary that helps to enhance city resilience.
	(U2S2) Assess the potential impacts of climate change on ecosystems and biodiversity in order to identify vulnerable ecosystem and therefore, vulnerable ecosystem services.	(U2M2) Promote awareness and understanding of climate change and its potential impacts on ecosystem services and society.	(U2A2) Adopt climate change prevention actions such as NBS.

Note: (U2R1) Promote and establish transboundary agreements and collaborations to support the protection and management of transboundary ecosystems. appears in the rightmost column aligned with the U2A1 row.

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(U2M3) Identify ecological ´hotspots´ (areas with outstanding biodiversity or a high concentration of biological values).	(U2A3) Protect and restore important ecosystems located in the urban and peri-urban area that directly provide important ecosystem services to the city.

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