SMART MATURE RESILIENCE

DELIVERABLE 3.5: SYSTEM DYNAMICS SIMULATION MODEL: CITY RESILIENCE DYNAMICS TOOL

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EXECUTIVE SUMMARY

The main objective of the SMR project is to develop the European Resilience Management Guideline (ERMG) that aims to help in the operationalization of the resilience building process of European cities. This ERMG integrates five complementary tools that will enhance significantly the CITY[1] resilience defined as the ability **"to resist, absorb, adapt to and recover from acute shocks and chronic stressed 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".**

These five tools are: 1) a Resilience Maturity Model (RMM), 2) a Risk Systemicity Questionnaire (RSQ), 3) a Portfolio of Resilience Building Policies (RBP), 4) a City Resilience Dynamics tool (CRD) and 5) a Resilience Information Portal.

This report focuses on the fourth tool, the CRD model, and it explains the methodology used to develop the tool, in addition to describing the tool and its features. The methodological approach included a literature review in order to gather information about simulation models and iterative learning environments. Furthermore, two workshops, in Glasgow and in Donostia/San Sebastian, were arranged in the second year of the SMR project to validate the different versions of the tool. These workshops also served as an opportunity to conduct several questionnaires in order to gather data required for the development of the tool, in particular with respect to the relationships among the RMM policies. Subsequently, the tool was tested in three cities in order to validate its usefulness as i) a training tool and a learning mechanism for the cities, as well as ii) a tool which can support crisis managers in cities in their decision making process.

The CRD tool aims at providing a training tool for cities to understand and learn about how the resilience building process should be in cities and also, to understand the functioning of the RMM and the dynamics of the resilience policies defined in the RMM. This tool complements the RMM and the RBP tools since it explicits the dynamics of the resilience policies and the interrelationships among them. Furthermore, it shows how the resilience level of the city will improve taking into account the strategy followed regarding the policy implementation.

[1] The SMR Project defines the concept of CITY as an environment that involves all the relevant stakeholders in the resilience building process. This concept is further explained in Section 4.2.

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1. INTRODUCTION

The severe consequences of the natural disasters that human societies have suffered in the last two decades such as the Indian Ocean tsunami in 2004, the Katrina and Sandy hurricanes in 2005 and 2012, the Haiti Earthquake in 2010, the East Japan Great Earthquake and Tsunami in 2011, the earthquake in Nepal in 2015, and the most recent disasters such as the earthquake in Mexico and the hurricane Irma in the Atlantic Ocean have overwhelmed the response capacity of cities. At the same time, the future is likely to bring even more challenges for cities, since it is expected that the number of disasters will continue increasing due to climate change and dense settlements in coastal and other disaster-prone areas. In addition, the dependency of current society on critical infrastructures may act as a stress multiplier for a whole range of social, environmental or economic challenges that a city may face.

Nowadays, most of the world's population live in cities, and according to forecasts, an increasing number of people will live in cities in the coming decades (100 Resilient Cities, 2016; Prior et al, 2013). As cities continue to grow, there is an urgent need to work toward building cities' resilience to the effects of a wide spectrum of disasters, ranging from acute shocks such as floods, droughts, and earthquakes to chronic shocks such as climate change, or environmental pollution (Godschalk, 2003; Prior et al, 2013; Weichselgartner and Kasperson, 2010).

Resilience thinking supports the transition from disaster management to an all-hazards approach, placing the emphasis on the ability of a complex system to deal with shocks and long-term stresses (Singh-Peterson et al., 2015). Resilience management expands the scope of risk management, in addressing complexities that characterise the operation of large integrated systems, considering known as well as unforeseen threats (Linkov et al. 2014). In this respect, the creation of more resilient cities or communities allows them to withstand and recover from shocks and stresses, being able to adjust plans and procedures prior to, during and following new or unexpected disturbances, so that they can maintain their function as needed throughout the disruption (Hollnagel, 2009).

Current literature and international initiatives such as the Rockefeller Foundation through its 100 Resilient Cities program and the United Nations Office for Disaster Risk Reduction (UNISDR), through its Making Cities Resilient Campaign, provide a broad set of frameworks, which include characteristics and priorities for building resilient cities (Johnson et al. 2014; Shaw, 2012; UNISDR, 2005; UNISDR, 2015; 100 Resilient Cities, 2016). However, there is still the need to provide guidance for the operationalization of resilience for a practical application of resilience concepts in decision making and planning. Operationalization entails making resilience concepts useful and useable beyond their theoretical context to policy makers and managers. In order to find a way to address this need, the SMR project is developing, testing and validating the European Resilience Management Guideline (ERMG).

This ERMG builds on five complementary tools that will enhance the anticipation and the coordination across different stakeholders and will enable addressing risks and opportunities to facilitate planning and decision-making process. These five tools are: 1) a Resilience Maturity Model (RMM), 2) a Risk Systemicity Questionnaire (RSQ), 3) a Portfolio of Resilience Building Policies (RBP), 4) a City Resilience Dynamics (CRD) tool and 5) a Resilience Information Portal.

This deliverable focuses on the fourth tool, the CRD tool model. The CRD tool is composed of two parts: a SD model where the main structure of the model is defined and a graphical user interface where the interaction between the user and the model is performed. The SD model defines the main variables and the relationships among the main variables and the graphical user interface facilitates the usability of the tool for the cities and understanding the results. In general, the CRD tool allows cities to better understand the RMM and support the decision making process when defining the strategy towards resilience building process. It allows testing different policy options and understanding the temporal order in which the policies should be implemented in order to improve the city resilience level.

In the following three sections the RMM is briefly presented followed by the contribution of the CRD tool and the requirements the CRD tool should fulfil to support cities in their resilience journey.

1.1. THE RESILIENCE MATURITY MODEL

Maturity models provide an approach to support agents in improving various types of organisational processes and to improve maturity with respect to the various dimensions in question (Antunes, Carreira, & Mira da Silva, 2014). A maturity model is a structured sequence of stages that describes the evolution of an effective process at different stages of development, from an initial stage to a more advanced stage (Wendler, 2012). A maturity model describes the trajectory of an organisation over time through stages of increasing maturity measured by its capability to engage with certain processes (Wendler, 2012). The starting stage stands for an initial stage that can, for instance, be characterized as an organisation having few capabilities with regards to the domain under consideration. At more mature stages, activities are performed more systematically and are defined and managed better by the organisation (Becker, Knackstedt, & Pöppelbuß, 2009). Therefore, the highest stage represents a conception of the highest maturity. As well as advancement on the evolution path between the two extremes involves a continuous progression regarding the organization's capabilities or process performance.

The SMR project has developed a Resilience Maturity Model (RMM) that comprises five well-defined maturity stages (Starting, Moderate, Advanced, Robust, and verTebrate) to guide cities through the ideal path of building resilience (see D3.1). Each of these maturity stages includes a description of the objectives for each stage, the agents involved at each maturity stage, and a set of resilience building

policies to implement in order to advance to a higher maturity stage (see D3.1). In addition to the five maturity stages, the RMM is structured according to four resilience dimensions: Leadership and Governance, Preparedness, Infrastructure and Robustness and Cooperation. These four dimensions are also divided into 10 sub-dimensions. Therefore, policies are classified depending on their maturity stage and their resilience dimension (see Figure 1).

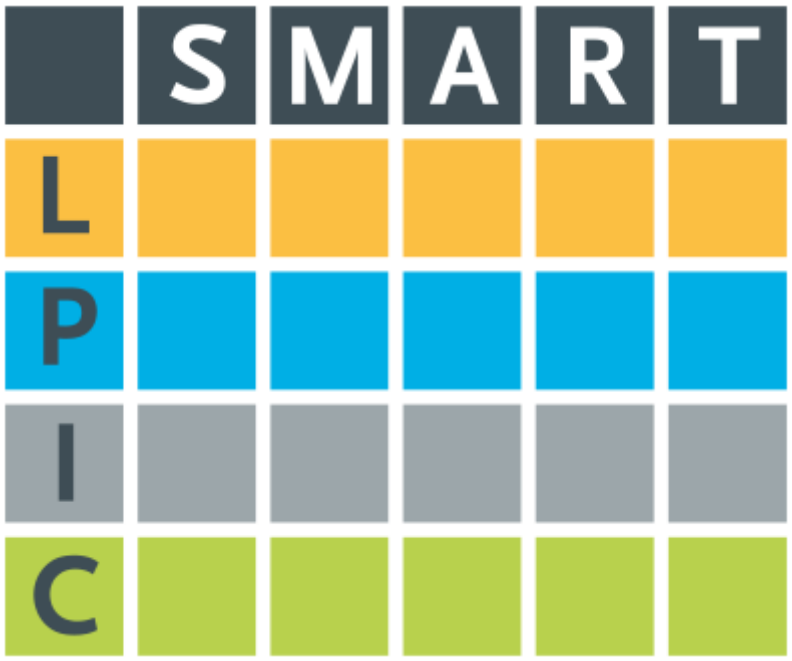

Figure 1: The main structure of the Resilience Maturity Model

The presented policies are inter-related with one another by, as are organised around the incrementally advancing maturity stages. Consequently, the city's chosen strategy regarding the policy implementation order will determine the efficiency of how likely they are to reach a higher maturity stage. Therefore, the RMM provides guidance to cities on the specific resilience policies that they have to implement at each of the maturity stages in an efficient way.

1.2. CONTRIBUTION OF THE CRD TOOL

The aim of the City Resilience Dynamics (CRD) tool is to encapsulate the most important aspects of the RMM and help crisis managers to diagnose, explore and learn about the resilience path that cities need to follow to improve their resilience levels.

The CRD tool is primarily designed to assist CITIES in understanding the functioning of the RMM and to provide a training tool to learn about how the resilience building process should be.

From the SMR project perspective, the use of the CRD tool can contribute to cities in the following areas:

- **Test different policy options**: The simulation tool provides a tool for the cities to test different strategies regarding the implementation order of the RMM policies. The results will vary depending on the implemented strategies, and therefore, the cities can determine which strategy could be more suitable to efficiently improve their resilience level.
- **Understand the RMM structure, the dynamic implications and the precedence relationship between policies:** The simulation tool has been developed based on the RMM. As described above, the RMM is a strategic tool that provides a roadmap about how the resilience process may be through the policies defined in each stage. The aim of the CRD tool is to make explicit the structure of the RMM and its functioning, as well as the dynamic implications among the policies which are defined through the precedence relationships among the policies. If the user does not follow the established precedence relationships, the model will alert the user and will show how the precedence relationships should be applied.
- **Improve awareness of counter-intuitive consequences of the implementation of policies:** The RMM establishes the temporal order in which the policies should be implemented to efficiently improve the resilience level of the cities. Based on these relationships, the CRD tool informs users about the effectiveness of the implemented strategy based on the precedence relationships defined in the RMM through indicators. If the relationships are not implemented in the expected order, the efficiency of the implementation of the resilience building process will decrease, and the user will be alerted about it.
- **Help crisis managers make decisions:** The tool allows crisis managers in cities to formulate the strategy that they need to follow to use efficiently the available resources, and to obtain a maximum level of resilience in the city. The CRD tool can help visualizing the process of how the ideal budget should be allocated throughout the resilience building process.

The CRD tool is not a predictive tool suggesting the next steps to be taken to achieve resilience, but it is a reflexive tool that allows the user to learn about the resilience building process. The aim is that after testing several strategies and with the help of the guiding messages, the user is able to understand and learn how the resilience building process works and how the optimum path can be obtained.

1.3. FULFILLMENT OF THE CITY REQUIREMENTS THROUGH THE SIMULATION TOOL

In D2.5, general requirements of the European Resilience Management guideline and specific requirements that each tool should fulfil were gathered from the cities based on four workshops conducted in WP2. Therefore, when developing the tools and the resilience management guideline it is important to verify that the general and specific requirements defined in D2.5 are effectively addressed and fulfilled.

The following tables explain the general and specific requirements that were defined for the CRD tool and how these requirements have been accomplished.

1.3.1. GENERAL REQUIREMENTS APPLICABLE TO ALL THE EUROPEAN RESILIENCE MANAGEMENT GUIDELINE TOOLS

Requirement	Accomplishment explanation
User friendly tools tailored to relevant stakeholders	The development of the CRD tool was conducted in collaboration with the SMR city partners in order to construct a user-friendly interface. The CRD tool's graphical user interface is very intuitive, and so whenever the mouse cursor is placed over a button or a sentence, additional information is provided. Furthermore, a user manual is available as part of the tool.
Tools developed should complement the tools, indicators, policies, methods and procedures that are currently being used in cities	The simulation tool has been developed based on the content in the RMM. Furthermore, through different activities during the review workshops, we gathered information about how the resilience building process is conducted in practice. Therefore, the tool presents what the resilience building process is.
Guideline to enable prioritisation of resilience building policies for CITY with respect to infrastructure resilience, climate adaptation and social issues	Through precedence relationships, the CRD tool defines the temporal relationships that exist among the policies and this allows the cities to prioritize among the policies that should be implemented in practice in order to face more efficiently

	risks related to critical infrastructure, climate change and social dynamics.
Need to standardize the resilience building process	All of the names of the stages, dimensions, sub-dimensions, and policies have been taken from the RMM, therefore, they are standardized accordingly.

1.3.2. SPECIFIC REQUIREMENTS APPLICABLE TO THE CRD TOOL

Requirement	**Accomplishment explanation**
Tool or method to increase the awareness level of different municipality departments regarding the resilience action plan (or the facto plan)	The CRD tool aims to help crisis managers in cities to understand the resilience building process and know how the policies should be implemented in order to efficiently improve their resilience level. Therefore, the awareness level of how the resilience action plan should be implemented is stated in the simulation tool.
Tool to help visualization of plausible futures which test the impact of key decisions taken in the near-term including those concerning resources and strategic investments	Based on the resources allocated and the strategy followed when implementing the policies, the results regarding the effectiveness of the implemented policies will vary. Therefore, this tool helps to test beforehand the effectiveness of the taken key decisions.
Tool or method to visualize tangible outcomes after investing efforts and resources in the resilience building process	The input data for the model is the resources allocated to implement each policy. Based on this decision, the outcomes will vary and the effectiveness of the resilience building process will be different. Furthermore, the model allows the cities to parametrize the model for their own cities providing more real and particular results for the city.

Horizon-scanning of the major European challenges which are likely to affect resilience of our city	The tool covers all the policy areas which are embedded in the RMM and therefore, it helps the cities to be aware of current European challenges which the cities are currently exposed to.

2. STATE OF THE ART

Worldwide there have been twice as many disasters and catastrophes in the first decade of this century as in the last decade of the 20th Century (Government and Disaster Resilience Minitrack, 2016). During the aftermath of these disasters, there emerges an increased need for improving cities' resilience. However, how to best prepare for already known risks as well as the unexpected ones is a very complex endeavor that is still at an early stage as a field of research and practice.

Cities require mechanisms for evaluating policies designed to build resilience and more specifically, metrics for monitoring and assessing the performance of these policies and justify their investments in resilience. Additionally, the resilience measurement may contribute to raising awareness about the need for resilience and the required resources for this purpose (Prior et al., 2013). However, resilience can be difficult to measure because it is a complex and multidimensional concept.

In this regard, progress has been made to find suitable indicators and metrics that retain the resilience key attributes. Several dynamic tools could be applied for the evaluation of the designed policies and resilience strategies. These dynamic tools enable to study the evolution over time of the taken decisions, as well as test and evaluate their effectivity and learn to prioritize resources. Following, a resume of these tools is presented as well as the final used methodology to develop the simulation tool.

2.1. MODELLING METHODOLOGIES

Simulation tools enable to include dynamic behaviors through the evolution of the defined variables (Sarriegi, Sveen, Torres, & Gonzalez, 2009). Therefore, they allow to have a complete view of the defined system (Rinaldi, 2004)(Pederson, Dudenhoeffer, Hartley, & Permann, 2006) and to adopt a holistic perspective including social, environmental and economic aspects (Min, Beyeler, Brown, Son, & Jones, 2007).

To develop a simulation tool, different modelling methodologies can be found. Yet, choosing the most appropriate modelling methodology can prove to be difficult depending on the required purpose for the model. Therefore, different type of taxonomies have been developed. For example, Ouyand in 2014 defined 6 types of modelling methodologies (Network Based, Input-output, Agent-Based and System Dynamics, High Level Architecture and Empirical) and conducted a review regarding the studies on the field (Ouyang, 2014). Similarly, Sarriegi in (2009), evaluated the suitability of four modelling methodologies (Network Based, Input-output, Agent-Based and System Dynamics) to model different issues. Apart from that, Marshall et al. (Marshall, Burgos-Liz, IJzerman, Osgood, et al., 2015) introduced the "SIMULATE" checklist. This checklist recognizes eight problem requirements/characteristics of

simulation modelling methods that distinguish them from other modelling methods (more information Annex 1).

Taking into account the SMR's project characteristics and the existing modelling methodologies classifications, this literature review compares the characteristics, the scope and the boundaries of the three most used dynamic simulation approaches namely: System Dynamics (SD), Discrete-Event Simulation (DES), and Agent-Based Modelling (ABM). Several comparisons between the use of these three complex simulation modelling methods to each other took place in academic publications i.e. (Lorenz & Jost, 2006), (Borshchev & Filippov, 2004), (Marshall et al., 2015a), (Kelly et al., 2013).

Regarding modelling characteristics, these three modelling methods use computers to simulate systems from different perspectives. On the one hand, SD separates the system variable into either stocks or flows. SD searches for the cause-and-effect relations between these variables, to ultimately compose several feedback loops. These feedback loops interact with each other and are accounted for the overall system behaviour over time (Forrester, 1961). On the other hand, DES sees a given system as a set of entities. Each entity has a set of attributes, and consumes system resources. Over time these entities go through queues, and experience events, causing the overall system behaviour (Karnon et al., 2012). Finally, ABM looks at the system as a set of interacting autonomous agents. These agents, governed by their internal logic, interact with their environment as well as each other, to cause the overall system behaviour (Marshall et al., 2015) (more information Annex 1).

Moreover, concerning the model's purpose or the reason behind building the model, SD is the only method that supports stakeholders' engagement, both in terms of using the final model as well as during the modelling process. In addition to this, SD also supports users to understand better the connections existing between the defined variables in question. However, in order to deal with strategic problems, not only SD but also ABM could be used. Yet, to evaluate both tactical and operational issues, DES and ABM are recommended (Marshall et al., 2015) (more information Annex 1).

Regarding the differences of using one methodology or another, SD is the less conflictive modelling methodology taking into account SMR project characteristics (more information Annex 1). Both DES and ABM methodologies' building processes are slower than in the case of SD models as these methodologies are more dependent on data availability and modeler's skills level. Apart from that, DES and ABM cannot be escalated to the population size (Marshall et al., 2015b).

2.2. INTERACTIVE LEARNING ENVIROMENTS (ILE)

Most of the developed simulation tools both in the academic and commercial sector have been used for didactical or commercial purposes (Mayer et al., 2014). To do so, the built models are used as part of the Interactive Learning Environment (ILE) with the objective of facilitating interaction with the user.

Generally, an ILE is defined as a “software for educational purposes, for supporting the process of learning, where the focus is on learning through the interaction with the computer (human-computer interactivity)” (Sterman, 2000). ILE is referred to a management flight-simulator, microworld, business simulator, or management simulator by various publications (Maier & Größler, 2000; Qudrat-Ullah, 2014). They can be developed either for educational or research and validation purposes (Davidsen, 2000). For educational purposes, ILE wishes to change the mental models of their users, while for research and validation purposes ILE aims at identifying their users’ mental models.

ILE has an ability to engage user producing a highly positive impact on them (Guillén-Nieto & Aleson-Carbonell, 2012; Mayer et al., 2014). As a consequence, ILE have become popular, especially considering the increasing role of technologies in modern societies (Guillén-Nieto & Aleson-Carbonell, 2012; Kiili, 2005; Mayer et al., 2014), but also, because there has been an evolution in the teaching field. For example in (Guillén-Nieto & Aleson-Carbonell, 2012), an ILE is presented with the aim of improving users intercultural awareness, knowledge and communicative competences at the university level. However, in (Kuriger, Wan, Mirehei, Tamma, & Chen, 2010) an ILE called WeBlog is developed to demonstrate the benefits of implementing lean concepts in a company. In both cases users’ attention and motivation were high, and the theoretical concepts taught by the ILE were successfully transferred.

Multiple studies have shown that ILE can be effective when applied to education (Kebritchi, Hirumi, & Bai, 2010; Guillén-Nieto & Aleson-Carbonell, 2012; Mayer et al., 2014) providing high benefits in comparison to conventional methods (Wouters, van Nimwegen, van Oostendorp, & van der Spek, 2013). Ke (2009) pointed to content, context and the achieved competences as key factors for success. Sitzman added the necessity of ILE to be designed as an active learning tool and the importance of having ILE combined with other tools to ensure its success (Sitzmann, 2011). Finally, Hamari stated that simulating real world tasks and giving instant feedback help to develop successful ILE (Hamari, Koivisto, & Sarsa, 2014). Related to what these three authors say, Wouters et al (Wouters et al., 2013) described three main aspects to take into account to assure effectiveness and success of ILE: (1) change in cognitive process (via active learning), (2) affecting motivation (simulating real world tasks for example), and (3) provide the sensation of having learnt (via instant feedback).

As a final point in this section, ILE have proven to be successful educational tool in the context of public policies, both on the national and city levels (A. Abdelgawad et al. 2016;).

2.3. SIMULATION TOOLS APPLIED IN THE RESILIENCE BUILDING PROCESS

Different simulation models application can be found in the literature in the context of resilience. Some models are focused on critical infrastructures, whilst other models are focused on natural crisis such as floods or heat waves. A number of such models are presented below.

Hamani and Boudjema (2013) propose a model to deal with natural disasters and ensure the sustainable development of the region. The model helps to determine the risk level of a region based on a hazard and taking into account the resilience level of the area, and it determines the physical vulnerability level, the affected number of people and damage caused by the hazard. In order to obtain this information, the model integrates two systems: Geographic Information System (GIS) and DataBase Management System (DBMS) which provides information for the model (Hamani & Boudjema, 2013).

Regarding Critical Infrastructures, the Human Centric Systems in India developed an Agent Based Simulation to efficiently manage Critical Infrastructures during crisis. The Agent Based Simulation models a prototypical support operation that runs into different crisis severity levels and shows for each case the size of the crisis team that would be required. The model is able to simulate what if analysis with the resulted impact factor (Balaraman et al., 2016).

Similarly, yet in more detail, the School of Civil Engineering in China developed a simulation tool to prepare to face terrorist attacks in the power sector. The simulation model is based on a System Dynamics model which studies the downstream consequences providing the users with evaluations of the most affected sectors and the way they are affected. Therefore, the model increases the preparedness of the users for future events (Wu, Tang, & Wu, 2016).

Moreover, Adjetey-Bahun et al. (2014) propose a simulation model based on a network based model to assess the resilience level of a railway transportation system against a perturbation. The model helps to analyze the effect of having implemented the crisis management plans in order to improve the functioning of the system and reduce the effects of the perturbation to the passengers (Adjetey-Bahun, Birregah, Châtelet, Planchet, & Laurens-Fonseca, 2014).

Finally, it is worth mentioning a simulation game called MAFURIKO developed in 2016 by Delft University of Technology. The game has been created due to the recurrent floods in Kenya with the objective to enhance the capacity of Kenyan citizens on flood risk reduction, so that citizens could work with the Kenyan Government to prevent and prepare future floods. The game is based on ArcGIS software that relates different scenarios where the user needs to take decisions to step forward. The game is programmed by using Python language. Depending the taken decisions, the scenarios will

change. All the defined scenarios are related to floods and particularized to locations in Kenya (Onencan, Kortmann, Kulei, & Enserin, 2016).

2.4. TOOL AND TECHNOLOGY TO DEVELOP CRD TOOL

Taking into account both the SMR's simulation tool's requirements and the characteristics of available modelling methodologies and the ILE presented above, the design of the model has been determined.

On the one hand, to develop a successful ILE, a cloud/web-based and fully client-side ILE has been used. Cloud/web-based approach exclusively provides features like lower cost, agility, and scalability (Nakazawa, Koizumi, & Hirasawa, 2012). Cloud/web-based approach makes the simulation tool easily accessible by the cities. Being cloud/web-based eliminates the need for any installation other than the web-browser which is, if not available by the operating system, very easy to install (Aljenaa, Al-Anzi, & Alshayeji, 2011; Kitanov & Davcev, 2012; Masud & Huang, 2012; Nakazawa et al., 2012).

On the other hand, SD modelling methodology seems to be the most appropriate method due to the following reasons:

- It models the problems and interactions occurred between elements of a system.
- It can simulate the short and long term strategic policies and intended/unintended consequences and incorporate feedback loops that affect the system.
- It can be easily wrapped into a user-friendly interface that allows user to simulate the model.
- It can be designed to take external inputs to influence the model results.
- It engages stakeholders as they are part of the model building process.

Different software packages were suitable for the construction of the SD model. At first Vensim[2] software was used. Vensim is an integrated environment for the development and analysis of SD models. It runs on Windows and Macintosh computers to simulate the dynamic behaviour of systems that are impossible to analyze without appropriate simulation software, because they are unpredictable due to many influences, feedback, etc. It also helps with causality loops identification and finding leverage points. Vensim provides some other dynamic functions like arrays, Monte Carlo sensitivity analysis, optimisation, data handling, application interfaces and others" (Azar, 2012).

[2] Vensim software was "originally developed in the mid 1980s for use in consulting projects. Vensim was made commercially available in 1992 by Ventana Systems, Inc. (Harvard, Massachusetts) (http://www.vensim.com).

Nonetheless, Vensim still requires another tool to make the model cloud/web-based. To solve this issue, different solutions were considered. Eventually, InsightMaker was selected among the following options:

- Forio Online Simulations which provides two different solutions:
    1. Forio Simulate (http://forio.com/simulate/)
    2. Epicenter (http://forio.com/products/epicenter/)
- iMODELER (http://www.consideo.com/)
- Insight Maker (https://insightmaker.com/)
- Sysdea (https://sysdea.com/)
- isee Exchange (https://exchange.iseesystems.com)
- BROADVIEW (http://getbroadview.com)

InsightMaker is an open-source tool distinguished by being totally client-sided. It also gives the modeller freedom on where she/he want to store the model, compares to, e.g. Forio Online Simulations that can also achieve the same goal, except that we are depending on the third-party server for processing the simulations. Yet, to make our CRD tool, we had to rebuild our SD model using the InsightMaker modelling tool, and continue to model directly in InsightMaker in the further changes/development of CRD tool.

3. RESEARCH METHODOLOGY

In this section, we explain the research methodology that has been conducted to develop the CRD tool. Several iterations were undertaken for the development of the CRD tool as part of two SMR workshops (see Figure 2).

First, an initial and simplified version of the model was designed with 19 out of the 98 policies of the RMM. This version was evaluated in the workshop conducted in Donostia/San Sebastian with experts from cities. Furthermore, a questionnaire was carried out to validate the temporal relationships among the policies. Based on the comments and improvement areas obtained from the workshop and the results gathered from the questionnaire, an improved version of the CRD tool was developed. This improved version was again evaluated in the workshop conducted in Glasgow. Moreover, a questionnaire was carried out to gather data for the main parameters of the model. Based on the comments and suggestions gathered from the workshop and the data gathered for the main parameters of the model, the final version of the tool was created (see D3.2). The final version of the tool has two versions: the reduced version with only 19 policies and the extended version with 45 policies. The reduced version aims at facilitating the understanding of the tool and its functioning for the new users whereas the extended version covers all the policy areas mentioned in the RMM. Even if the extended version does not have the 98 policies of the RMM, the selected 45 policies have been selected carefully in order to represent the whole RMM. Indeed, for each dimension at least one policy in each maturity stage has been selected. Apart from that, taking into account that the CRD tool has been developed for both enabling testing different policy options and helping crisis managers make decisions, it was considered interesting to maintain the policies that add new actions or processes to be implemented particularly in each maturity stage. In detail, 8 policies were maintained in the Starting stage, 14 policies in the Moderate stage, 9 policies in the advanced stage, 7 policies in the Robust stage and 7 policies in the Vertebrate stage. Therefore, the Moderate stage is the one with more policies as it is the stage in which higher amount of new actions are implemented.

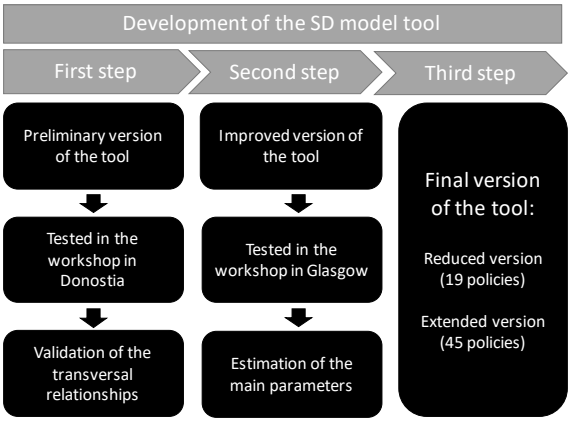

Figure 2: Research methodology

3.1. WORKSHOP IN DONOSTIA

To validate, evaluate and assure the effectiveness of the preliminary version of the tool, a one-day workshop was conducted the 6th of March of 2017 in Donostia with a total of 30 participants from the cities of *Bristol*, *Rome*, *Riga*, *Glasgow*, *Vejle*, *Kristiansand* and *Donostia* in addition to Smart Mature Resilience project academic partners: Tecnun, University of Navarra, The Centre for Integrated Emergency Management (*CIEM*) of the University of Agder, Linköping University (*LIU*), *University of Strathclyde,* the German Institute for Standardization (*DIN*) and the International Council for Local Environmental Initiatives (*ICLEI)*.

First, a general presentation was performed to explain the main objectives of the tool and the structure of the tool. Then, in a tutorial way presentation, the functioning of the tool was illustrated to the participants. Following the main presentations, the participants worked with the CRD tool through a number of subsequent activities. All of the SMR partners were engaged in the exercises and they were divided into groups. Each group had a moderator and a recorder in order to help participants in the use of the tool as part of the undertaken exercises. The model was tested in two modes to provide insights on its usefulness to function as a laboratory as well as a training tool. In the *laboratory* version, the tool did not provide users with guiding messages when they implemented in a different order than it is recommended by the tool. That allowed participants to experiment with the tool in order to understand better the features of the tool. In addition to this, in the *training tool* version, the tool provided guiding messages to the users to indicate what the expected temporal order of the implementation of the RMM policies should be. The exercises conducted were divided into two main groups based on their content: some exercises were oriented towards validating the user interface of the tool, and other exercises were oriented towards the validation of the main structure of the SD model. The table below shows a brief overview of the performed exercises:

GOAL	DESCRIPTION OF EXERCISE
USER INTERFACE VALIDATION	**Exercise 1: Free play with the CRD tool** In this session, participants were free to use the simulation tool as they wish, and to familiarise themselves with its features. They were also encouraged to pose questions to Tecnun and CIEM in order to better understand the tool.
	Exercise 2: Trying the CRD tool having a TARGET in the laboratory mode, NO guidance (no messages system) The target was: ''achieving at 1 (or 100%) on all 4 SMR dimensions' indicators with the lowest possible cost by the end of the 40 years simulation period''. Participants were asked to calculate the cost of their decisions by the end of each scenario (40 years). It was important to realise how much they have spent per policy and hopefully understand why one policy costs more than another to have at the same implementation level (taken into consideration that in the current version of the CRD tool all policies cost the same though)
	Exercise 3: Trying the CRD tool having a TARGET in the training tool mode, WITH guidance (with messages system) The target was again: ''achieving at 1 (or 100%) on all 4 SMR dimensions' indicators with the lowest possible cost by the end of the 40 years simulation period''. The participants were guided in calculating the cost of their decisions by the end of each scenario (40 years). It was important to realise how much they have spent per policy and hopefully understand why one policy costs more than another to have at the same implementation level (taken into consideration that in the current version of the CRD tool all policies cost the same though) The participants were also asked to answer two questionnaires: one about the user interface and its functionalities, and the other one about the parameter estimation.

SIMULATION MODEL VALIDATION	**Exercise 1: Testing the structure of the simulation model** Participants were asked to discuss the available RMM policies and how they are related with one another. Participants were advised that there are two types of relationships between the RMM policies: • Linear relationships: within each sub-dimension the policies in the higher stages are dependent towards the policies in the lower stages • Transversal relationships: within each stage, the policies in different sub-dimensions are related each other The goal of the session was to validate the relationships among the policies: linear relationships and transversal relationships.
	Exercise 2: Validating the relationships among the policies: linear relationships and transversal relationships. Participants were provided with an A3 sheet that contained a Causal Loop Diagram of a current view of the causal relations among the SMR sub-dimensions with the aim of validating the transversal relationships. Then the participants were asked to give their opinion concerning these relations in terms of agreeing/disagreeing and suggesting new relations if needed. Then, they were provided with additional A3 sheets where they could draw their version of the connections between the SMR sub-dimensions, if the one provided by the organizers was far from their opinion. Moderators made sure that during this session participants understood the concept of causal connections and in the end had a clear understanding of what were the positive and negative connections, how they work, and what are the main differences between them.

Annex 2 resumes the main comments gathered from the workshop and Annex 3 resumes the questionnaire and main results obtained regarding the transversal relationships of the policies.

As an overall result, the participants agreed the preliminary version of the simulation tool needed to be more realistic in the future versions. To do so several changes presented in Annex 2 were implemented

before Glasgow's workshop such as enabling the user to simulate budget cuts or applying different weight to the relationships between policies (Annex 3). Apart from that, they also stated the need to have a user friendly interface to assist the user while using the tool. In order to improve this aspect different changes were made (Annex 2), but the most significant one was the development of a user guidance presented in Annex 7.

3.2. VALIDATION OF THE TRANSVERSAL RELATIONSHIPS AMONG THE POLICIES

The SD model within the CRD tool represents the structure of the RMM and determines the relationships between policies. The RMM is composed of five different maturity stages and four resilience dimensions, which are divided into different sub-dimensions. As a consequence of this structure, two types of relationships have been defined: linear relationships and transversal relationships.

Linear relationships refer to temporal relationships that exist among the different maturity stages. This means that policies in the lower maturity stages should be developed to implement the policies in the higher maturity stages. For example, within each sub-dimension, policies in the "Starting" stage should be developed in order to implement the policies in the "Moderate" stage, and similarly, policies in the "Moderate" stage should be developed to implement the policies in the "Advanced" stage.

Transversal relationships refer to relationships among the policies in different sub-dimensions. Although the policies have been divided into different sub-dimensions, these sub-dimensions are interrelated with each other. Therefore, within each maturity stage, the relationships among the sub-dimensions have been defined. Thus, if two sub-dimensions are related, the policies within the two sub-dimensions will also be related each other. Moreover, these transversal relationships are maintained from one stage to the next one. For example, as seen in Figure 4, there is a transversal relationship between the sub-dimensions L4 and P1. Therefore, in all the stages, the policies within L4 and P1 will be related each other as it happens between policies L4M1 and P1M1 in the moderate stage and between the policies L4R1 and P1R1 in the robust stage.

The CRD tool was built taking both linear and transversal relationships into consideration. As a result, when the policies are not implemented in the correct order, they will not be effective, and consequently, the user can inefficiently spend money on implementing policies out of order, without improving the city resilience. The indicators' values are obtained through the average of the sub-dimensions, which are calculated based on the sum of the implementation rate of each policy on that sub-dimension multiplied by its effectiveness. For the preliminary version of the tool, a preliminary version of the linear and transversal relationships were defined (see Figure 3).

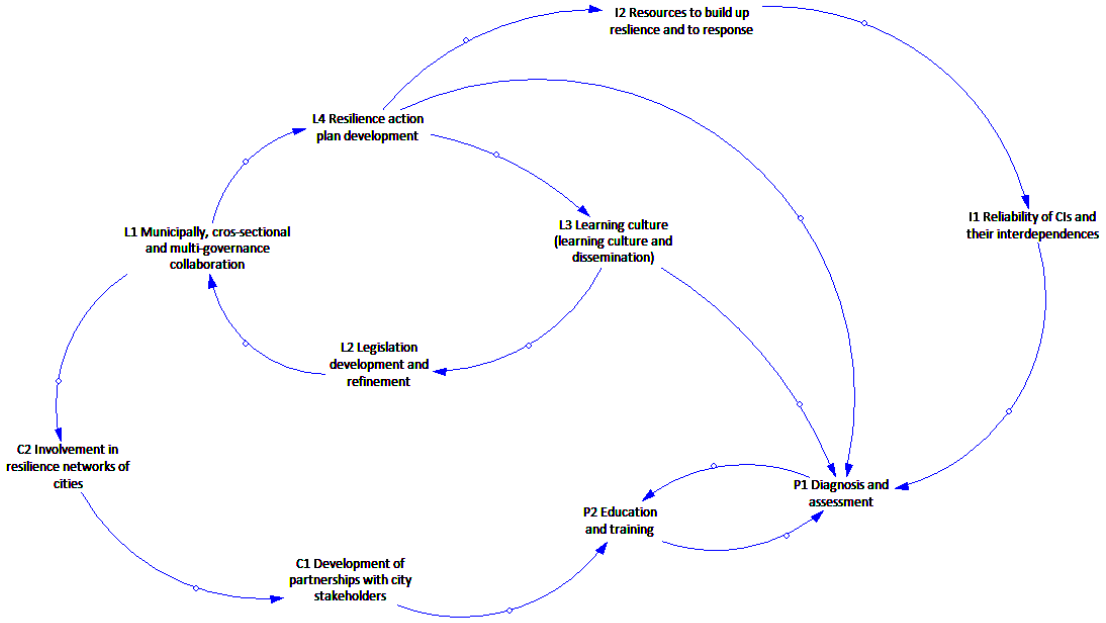

Figure 3 Preliminary version transversal relationships

The linear relationships were already defined in the RMM since they are explicitly stated in the maturity model based on the five maturity stages. However, a validation was needed for the transversal relationships. An exercise was conducted in Donostia workshop to validate this preliminary version of the relationships but no consensus was achieved. Therefore, after the workshop, a survey was carried out to improve the validation of transversal relationships. The questionnaire used in the survey was developed based on the results obtained from the workshop in Donostia. The aim was to achieve a consensus about the transversal relationships. All of the SMR city partners answered the questionnaire and as a result some consensus was achieved about the transversal relationships. Annex 3 presents the questionnaire used to get the information and the obtained results. As a conclusion of the questionnaire, some transversal relationships were not validated, others were considered “weak” relationship as the obtained rating was low and others were validated. Figure 4 illustrates the final resulted diagram of the transversal relationships at a resilience dimension level where the dashed lines represent the “weak” relationships.

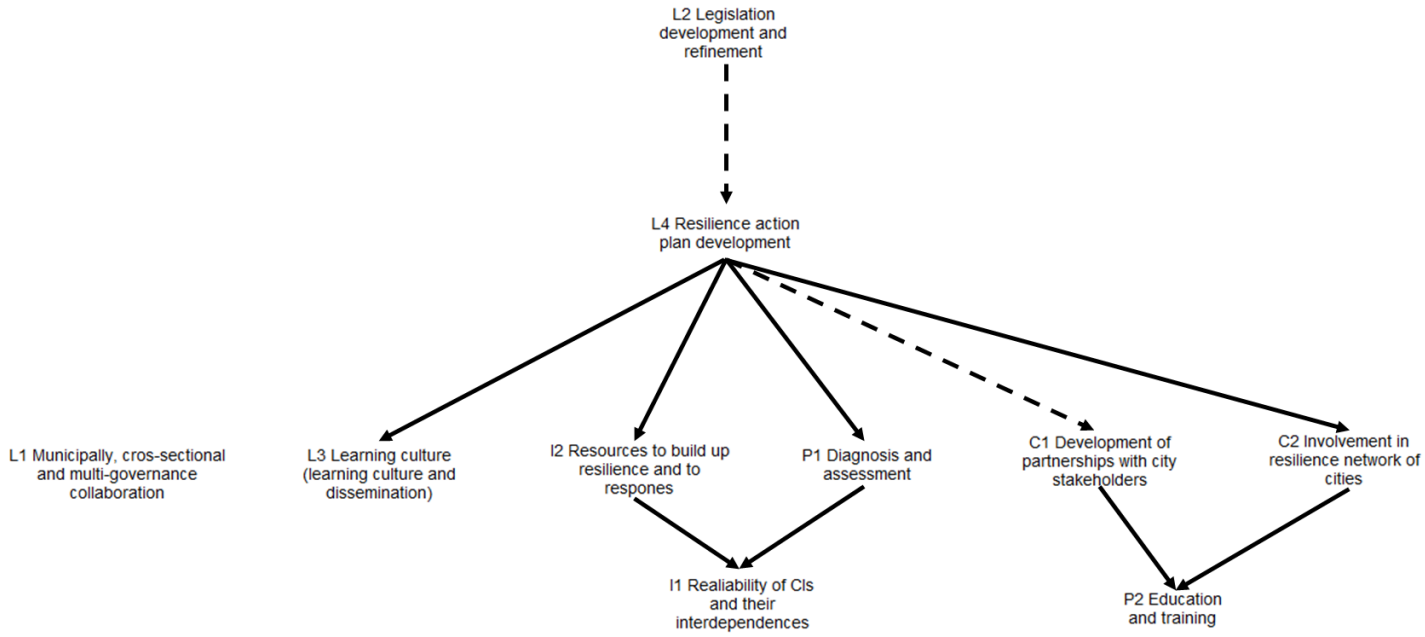

Figure 4 Transversal relationships at a resilience dimension level

3.3. WORKSHOP IN GLASGOW

In order to validate, evaluate and assure the effectiveness of the CRD tool, a one-day workshop was conducted the 17th of March of 2017 in Glasgow with a total of 30 participants from the cities of *Bristol*, *Rome*, *Riga*, *Glasgow*, *Vejle*, *Kristiansand* and *Donostia* in addition to Smart Mature Resilience project academic partners: Tecnun, University of Navarra, The Centre for Integrated Emergency Management (*CIEM*) of the University of Agder, Linköping University (*LIU*), *University of Strathclyde,* the German Institute for Standardization (*DIN*) and the International Council for Local Environmental Initiatives (*ICLEI)*.

All the SMR partners were engaged in the exercises and they were divided into small groups. Each group had a moderator and a recorder to help participants with the use of the tool as they engaged with the facilitated exercises.

The exercises performed during the workshop had three main objectives: technical validation of the tool, validation of the requirements of the tool and playing with the tool to better understand its functioning.

GOAL	DESCRIPTION OF EXERCISE
TECHNICAL VALIDATION OF THE TOOL	**Exercise 1:** A general presentation was performed to recall the main objectives of the tool and the structure of the tool. Then, the functioning of the tool was explained to participants, highlighting the improvements included in the tool. Following the presentations, with the aid of assigned facilitators, participants were given time to play with the tool and make comments regarding any technical issues they could have.
VALIDATION OF THE REQUIREMENTS OF THE TOOL	**Exercise 2:** A general presentation was performed explaining the requirements that the tool should fulfil and explaining how each of these requirements were fulfilled by the CRD tool. Then, experts had to give feedback about to what extent they thought the CRD tool fulfilled the requirements and provide comment and opinions about that.
PLAYING WITH THE TOOL	**Exercise 3:** Participants were asked to play with the tool to better understand the functioning of the CRD tool and the logical structure behind the model. To do that, the participants were asked to achieve a target regarding the resilience level with a given budget. After completing the exercises, the results obtained by each group were presented in a plenary session in order to compare the taken decisions and the obtained results in each group.

Annex 4 resumes the main comments gathered from the workshop regarding the improvement of the CRD tool and Annex 5 resumes the questionnaire and main results obtained regarding the requirements fulfilment.

As an overall result, the participants agreed the second version of the simulation tool was more realistic than the one presented in Donostia's Workshop, yet some improvements regarding the tool's ability to be particularized to each city were suggested. As a consequence, the final version of the tool not only enables the user to particularize policies' parameters to each city but also to the currency. Apart from

that, the comments concerning the user interface stated that with the changes made after Donostias's workshop the tool's new version has become user friendly.

3.4. ESTIMATION OF THE MAIN PARAMETERS OF THE MODEL

A questionnaire was carried out to obtain the data for estimating the main parameters of the model (see Annex 6). The main parameters of the model are the following ones:

- **Implementation cost of each policy:** the resources needed in monetary units for implementing a policy in practice. The city participants agreed that the main input data for building resilience is the available resources. These resources can be of different nature but in order to homogeneize and simplify the tool, we assume that all these resources could be represented as a general budget in terms of monetary units. Therefore, it is important to estimate how much budget is required for implementing a policy.
- **Implementation time of each policy:** the time needed for implementing a policy in practice.
- **Depletion time of each policy:** if the policy is not maintained or updated at all, the time needed to decrease the implementation level to zero and become obsolete the implementation level of the policy.

We asked the SMR city partners to give data about these three main parameters for each resilience policy defined in the CRD tool (in total there are 45 policies).

After obtaining the data, we analyzed the data and calculated the default values for the implementation costs of the policies based on the population and the GDP level of each city. For the default values we assumed a city of about 824.807 inhabitants and a GDP per capita of about 35.111,71 €/person which are the weighted average values of the cities taking part in the SMR project. To calculate the default values for the implementation time and the depletion time of the policies we calculated the average values obtained from the questionnaire (Annex 6). Although the CRD tool allows the users to adjust the values of the main parameters of the model to their city features, the default values were estimated based on the knowledge from experts. Table 1 summarizes the default main parameters of the CRD tool:

Table 1 Policies' main parameters' values

Policies	Implementation cost (€)	Implementation time (year)	Depletion time (year)

L1S2	114.353,57	4,3	6,1
L1M1	142.422,40	1,8	3,0
L1M3	883.562,16	6,4	8,3
L1M4	556.039,91	6,3	7,5
L1R1	205.316,80	4,8	4,8
L2A1	435.701,93	4,8	5,2
L2T1	192.283,42	2,7	4,9
L3A1	45.663,80	1,6	2,1
L3M1	168.820,36	3,0	5,2
L3T2	50.782,13	2,1	4,7
L4M1	192.441,27	2,4	5,1
L4R1	99.995,00	2,6	3,0
P1S1	199.884,34	4,2	3,7
P1M1	178.877,85	2,4	2,8
P1A1	187.085,00	2,0	2,7
P1R1	149.582,00	2,5	2,7
P1S2	100.772,78	2,6	2,3
P2S1	354.710,79	1,3	2,0
P2M1	359.822,65	2,1	2,3
P2A3	66.105,13	1,7	2,3

P2R2	212.294,45	2,0	2,3
P2T1	122.555,94	2,0	2,3
I1S3	220.802,53	2,1	2,7
I1S1	34.028,74	3,5	2,7
I1M1	164.882,50	2,8	4,0
I1M3	540.521,88	4,2	5,2
I1T1	622.149,69	4,4	5,2
I1M5	192.513,18	1,3	1,8
I2S2	37.728,08	1,7	3,0
I2M1	332.801,23	2,0	2,3
I2M2	185.518,64	3,3	3,3
I2A1	241.171,34	3,5	3,7
I2A4	355.378,30	4,5	7,2
I2R1	486.313,00	5,2	8,3
I2T2	56.887,10	2,3	4,7
C1S2	106.340,73	1,9	1,9
C1M1	79.681,59	1,3	1,6
C1A1	87.963,78	1,3	2,0
C1A4	135.893,35	1,7	1,4
C1R3	162.236,31	1,3	1,3

C1T2	206.282,25	3,8	3,7
C2M1	56.231,24	2,3	3,7
C2A2	97.463,70	2,7	4,0
C2R1	41.905,10	2,3	3,7
C2T1	102.582,02	2,7	4,3

Once the CRD tool was developed, three pilot tests were undertaken in order to validate the model. These pilot tests were hold in the cities of Donostia / San Sebastian, Glasgow and Kristiansand. The exercises performed in these pilot tests and the results obtained are explained in detail in section 5 of this deliverable.

4. CITY RESILIENCE DYNAMICS TOOL

The CRD tool composition is structured in two parts: on the one hand, a SD model which defines the logic of the model based on the RMM. On the other hand, a user friendly interface that interacts with the user in order to obtain the input data and show the results. The SMR simulation tool can be used by anyone, however it is tailored for the use by cities, specifically by practitioners who work on strategic organisational levels, and try to take a holistic perspective with regards to building resilience. Moreover, the SMR simulation tool is a general tool and cannot be particularized to any specific disasters. However, it is possible to adjust some parameters such as change the currency used by the tool to Euros, Pounds or Norwegian Kroners, as well as particularize the settings of the game to any city. This means that the simulation tool is a flexible tool yet it could be more flexible.

Regarding the functionality of the tool, the input of the SMR simulation tool are the policies defined in the RMM. When working with the simulation, the user is asked to choose the policy implementation order and how much resources they wish to invest in each policy. The main input data is the amount of resources/budget allocated to each policy. The city representatives agreed that the availability of resources is the main restriction in the resilience building process. Although the resources can be of different nature such as people, money, time etc. in order to simplify we assess all these resources in terms of monetary units. Therefore, the as input data, the user need to establish how much resources

are allocated to each policy. As a consequence, the SMR simulation tool shows the impact of the taken decisions through time evolution graphs and resilience dimensions' level indicators.

The SMR simulation tool is structured in three views; initial state views, decision- views and result-views. When users enter the tool they are directed to into the initial state view where the purpose and functionalities of the game are briefly described. Once the initial situation is established, the users move to the decision views where they can select how much money they wish to allocate to each policy. Finally, the result- view shows the results of the simulation based on the decision taken by the user (see more information in section 4.2.3).

4.1. SD MODEL DESIGN

The SD model behind the CRD tool includes a selected set of 45 (19 for the reduced version) RMM policies that covers all dimensions and sub-dimensions. The main requirement of the CRD tool is to teach its users about the importance of following the optimum implementation sequence defined by the RMM policies. Accordingly, in the CRD tool, the RMM policies are modelled at a general, rather than at detailed level. These policies are connected via linear relations within the same sub-dimension that matches the RMM policies' implementation recommended sequence, and via transversal weak and strong relations from one sub-dimension to another that were extracted from the SMR city partners via workgroup discussions which were followed by a survey explain in section 3.2. In detail, the difference between the weak and strong transversal relationships defined in the model resides on the thresholds defined for each case. Indeed, when a relationship between policies is defined as strong, based on the carried out questionnaire, the threshold has a value of 0,33 what means that until the antecessor policy has not reached an implementation level of 33% the predecessor policy will not have any effectiveness in its implementation. When the relationship between the policies is defined as weak, the predecessor policy will not have any effectiveness until the antecessor policy has reached an implementation level of 0.15.

The figures below (Figure 5 and Figure 6) resume the precedence relationships among the 45 policies defined in the CRD tool.

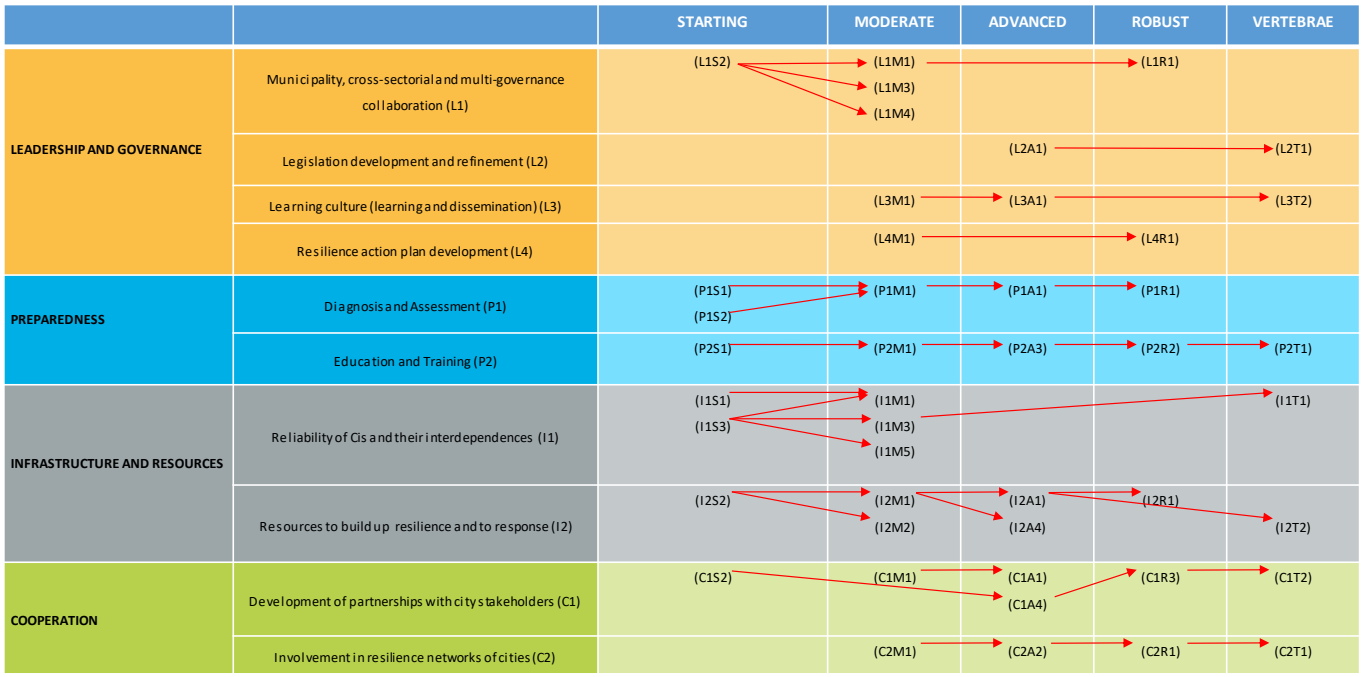

Figure 5: The linear relationships among the policies in the extended version

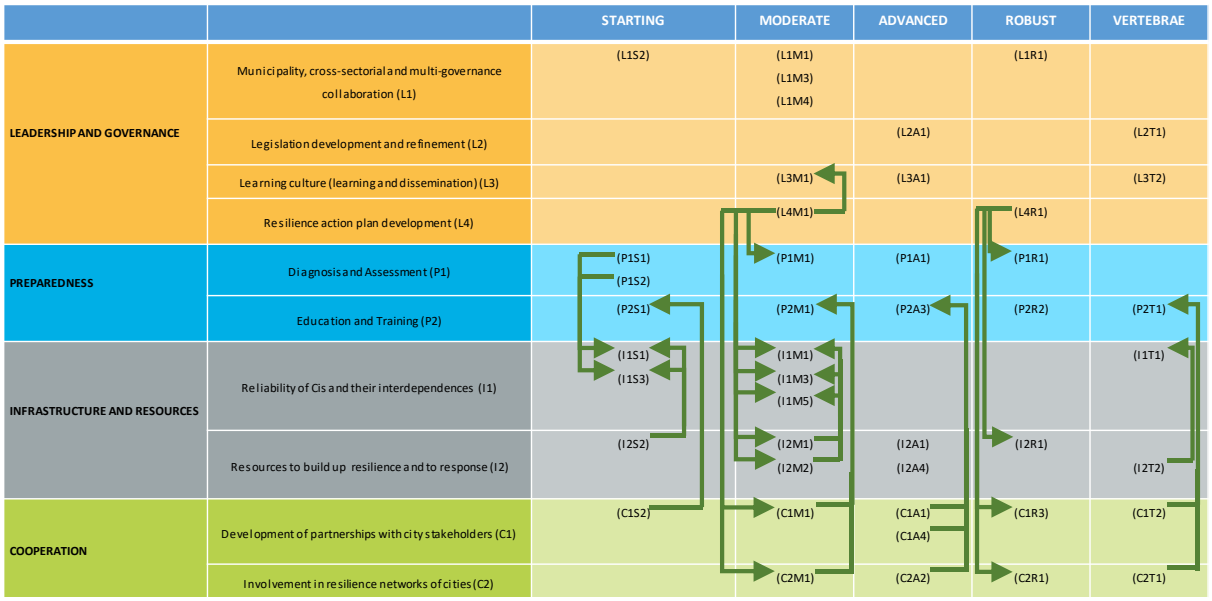

Figure 6: The transversal relationships among the policies in the extended version

The CRD tool informs its users about the city resilience performance in terms of four different dimensional indicators, in addition to showing them the cost of implementing the RMM policies. This

way the model represents a learning environment that is expected to help city partners to understand the different RMM policies, and to appreciate the relations between these policies.

The following subsections will explain the different sectors/sub-models of this SD model. Note that the model will be presented as a standard SD model, so that the readers are aware of the underlying approach behind this simulation methodology. A brief explanation and the meaning of the diagram in the next session is included.

4.1.1. SD DIAGRAM

The SD model is typically presented as a stock-flow diagram. The stocks represent the accumulation of values in a system. In the stock-flow diagram, the stocks are depicted as rectangles. The flows are illustrated as doubled arrows with valves, representing the inflow or outflow of materials to or from a system. In other words, a flow is the rate of change in a stock. For example, bank balance can be seen as a "stock". Deposits and interests can be seen as the "inflows" that increase the bank balance while withdrawals are the "outflows" that deplete the saving. Flows are typically measured over a certain interval time such as the amount of money saved over a month or a year A simplified version of stock and flow diagram can be seen in Figure 7. Mathematically a stock can be seen as accumulation or integration of net flows over time (sum of outflows subtracted the sum of inflows). The same diagram in figure 7 can be represented by the following equation:

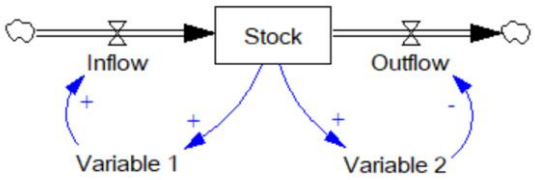

Figure 7 Stock and Flow Diagram

$$Stock_i = Initial\ Value\ of\ Stock_i + \int_0^t (Inflow_i - Outflow_i)\, dt$$

Likewise, the example of Bank balance can be translated into the following equation:

$$Bank\ Balance_i = Initial\ Value\ of\ Bank\ Balance_i + \int_0^t (Deposits_i - Withdrawals_i)\, dt$$

The links between variables in Figure 8 denote causality. A link from A to B means that A causes a change in B. The signs plus (+) and minus (-) by the arrowheads denote polarity. A positive causality will be marked as (+) which means an increase (decrease) in A yields an increase (decrease) in B. A causal link from A to B has negative polarity if an increase (decrease) in A causes a decrease (increase) in B (Sterman, 2000). The clouds in the beginning or in the end of inflow/outflow arrows are source and sink, which are not the part of the model.

The relationships between variables are defined as mathematical equations as well. Some variables need initial values or parameter values. These values were obtained from questionnaires circulated to the city, and the summary of parameterization process which can be found in Annex 3 and 6.

4.1.2. POLICIES IMPLEMENTATION

4.1.3. POLICIES IMPLEMENTATION

The SD model within the CRD tool depicts the RMM policies at the abstract level, i.e. one RMM policy. We use L1M2 policy in Figure 8 as an example of an RMM policy implementation in the model. Using the stock concept explained in Section 4.1.1, we treat the policy implementation level as an SD Level/Stock whose value fluctuates between 0% and 100%. If the value of the L1M2 Implementation Level is 0%, it means that the policy has not been implemented at all yet, and if L1M2 Implementation Level is 100%, it means that the policy has been fully implemented.

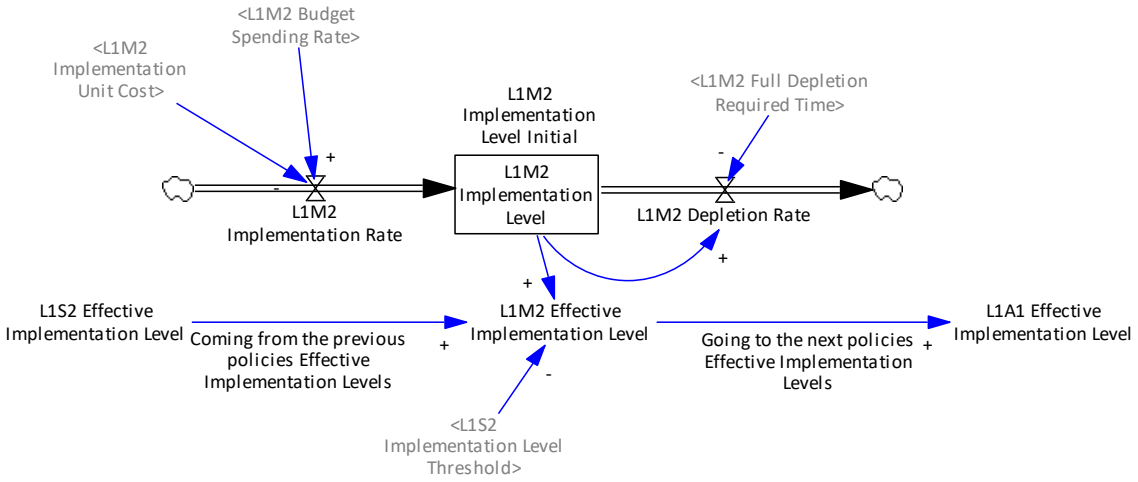

Figure 8: Policy Implementation Level

The *Policy Implementation Level* will be changed based on *Policy Implementation Rate* from one side (representing percentage of the L1M2 policy implemented per month which will add its implementation level), and *Policy Depletion Rate* from the other side (capturing the situation in which the policy is not maintained, which in turn will weaken *L1M2 Implementation Level*). This structure is repeated for all the policies. In Figure 8, a concrete example is presented using the policy L1M2 “Align, integrate and connect the resilience action plan with regional plans” to represent the main used for all the policies.

L1M2 Implementation Rate will increase the *L1M2 Implementation Level* as it can be seen in Figure 8. It is an effort to keep the policy in place over time which is determined by *L1M2 Budget Spending Rate* and *L1M2 Implementation Unit Costs*. Policy implementation level will become obsolete if it is not maintained or no resources are dedicated on the specific policy. The outdated process due to lacking policy maintenance is captured through the outflow. This outflow is dependent on *L1M2 Full Depletion Required Time*. This variable refers to the length of time when a policy maker starts ignoring a specific policy until it decays.

We provide the model explanation in two ways: descriptive and as mathematical notation. The latest is to make it clear that SD model is built on mathematical equations.

In mathematical notation, the Implementation Level of the any policy (denoted by the letter "i", i.e. policy i) is defined as:

$$IL_i = IIL_i + \int_0^t (IR_i - DR_i)\, dt$$

Equation (1)

Where:

Notation	Meaning	In Figure 8
IL_i	Implementation Level of Policy$_i$	*L1M2 Implementation Level*
IIL_i	Initial Implementation Level of Policy$_i$	*L1M2 Implementation Level Initial*
IR_i	Implementation Rate of Policy$_i$	*L1M2 Implementation Rate*
$\boldsymbol{DR_i}$	*Depletion Rate of Policyi*	*L1M2 Depletion Rate*

According to the RMM, a RMM policy cannot be effective until all preceding RMM policies (linear within the same sub-dimension and transversal from one sub-dimension to another) reach certain implementation levels, i.e. threshold values. These thresholds values vary depending if the relationship between policies is strong or weak. If the relationship is defined as strong then this value is 0.33 and if the relationship is defined as weak then this value is 0.15. The *Policy Effective Implementation Level* is defined as a piecewise function as follows:

$$EIL_i = \begin{cases} IL_i, & EIL_{i-1} > ILT_{i-1} \\ 0, & EIL_{i-1} \leq ILT_{i-1} \end{cases}$$

Equation (2)

Where:

Notation	Meaning	In Figure 8
EIL_i	Effective Implementation Level of Policy$_i$	*L1M2 Effective Implementation Level*
EIL_{i-1}	Effective Implementation Level of the policy previous to Policy$_i$	*L1S2 Effective Implementation Level*
ILT_{i-1}	Implementation Level Threshold of the policy previous to Policy$_i$	*L1S2 Implementation Level Threshold*
$\boldsymbol{IL_i}$	Implementation Level of Policy$_i$	*L1M2 Implementation Level*

The concrete example of Equation (2) is as follow: the effectiveness of the implemented policy (of L1M2 as an example) depends upon the full implementation of all preceding policies in L1 before L1M2, i.e. L1S1, L1S2 and L2M1 (policies within the same sub-dimension). If these preceeding policies are below 33%, then the effectiveness of the policy implementation will be zero. The effectiveness level will be visible if the three preceeding policies in this case (L1S1, L1S2 and L2M1) have their implementation level above 33%. The higher the effectiveness values of these preceeding policies are, the better the value of the Effective Implementation Level of Policy L2M1 will be. Note that the grayed variables such as <L1M1 Implementation Cost> or <L1M2 spending Rate> in the Figure 8 mean that these variables come from other sectors. To avoid repetition, these variables are explained in Section 4.1.3, Figure 9 as they refer to the same concepts.

4.1.4. POLICIES IMPLEMENTATION COST

In the SD model, there are two types of *Available Budget* levels, the first one is the general *Available Budget* which carries the total budget that the city can devote to implement RMM policies per year. The other type is the *Policy Available Budget* which every RMM policy included in the SD model has an instance of. The *Policy Available Budget* level refers the annual budget the city decided to devote to this RMM policy. The money carried by *Policy Available Budget* level moves to *Policy Used Budget* after being spent on implementing its respective policy.

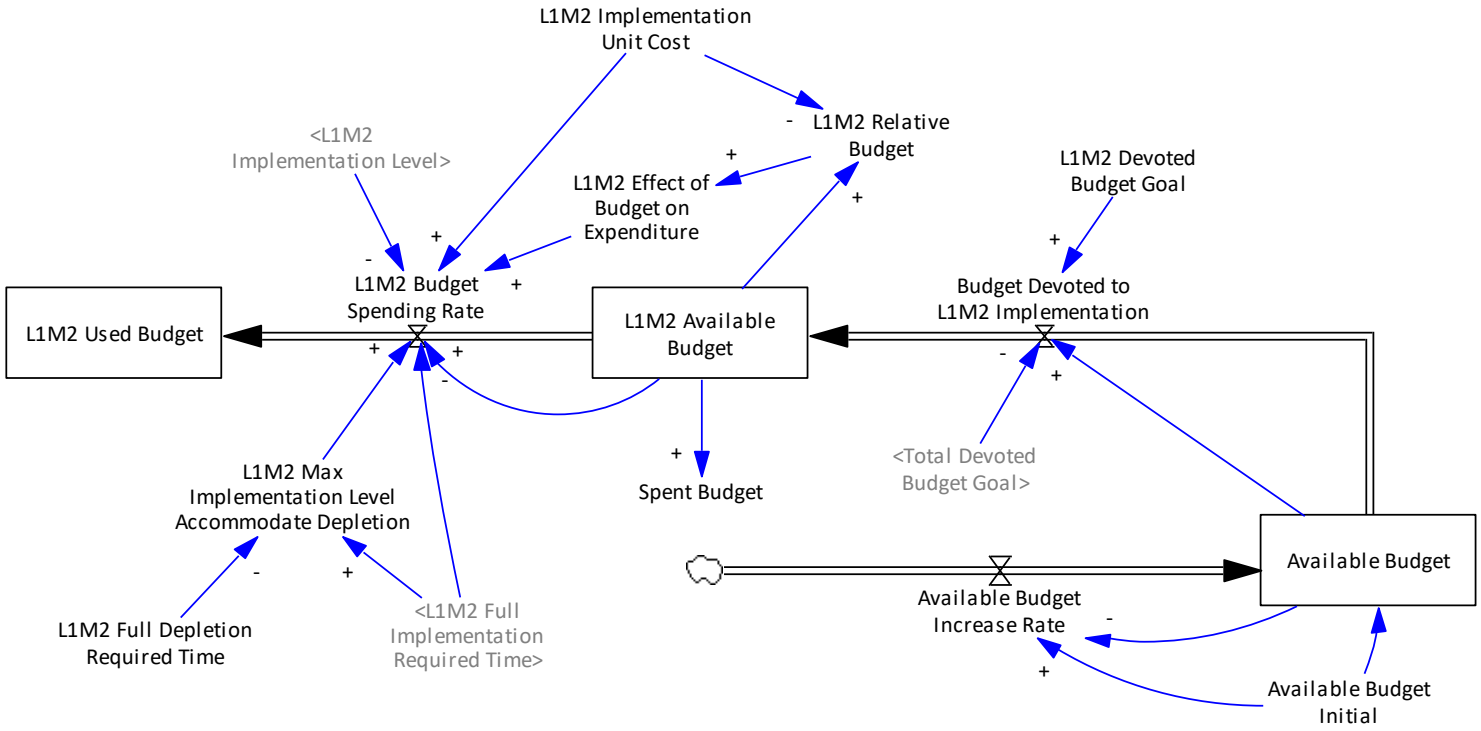

Figure 9: Available and Used Budget

The following equation shows the available budget for all policies:

$$AB = ABI + \int_0^t (ABIR - BDI_i)\, dt$$

Equation (3)

Where:

Notation	Meaning	In Figure 9
AB	Available budget for all policies	*Available Budget*
ABI	Initial available budget for all policies	*Available Budget Initial*
$ABIR$	The inflow to the available budget for all policies	*Available Budget Increase Rate*
$\boldsymbol{BDI_i}$	Budget devoted to implementing Policy$_i$ (Inflow to the available budget for Policy$_i$)	*Budget Devoted to L1M2 Implementation*

In equation (3), *Available Budget* (i.e. *AB*) means the total budget that the city can devote to implement RMM policies at a certain point in time. It depends on how much budget is initially allocated (i.e. *ABI*). For example, a city allocates 50,000 EUR for resilience building policies. Every year, the available budget *AB* will increase through the inflow *Available Budget Increase Rate* (i.e. the city either allocates regularly or increases the budget per year), and depletes when the funding is spent for various RMM policies. Equation (4) represents the same concept in equation (3). While equation (3) captures the overall budget that will be spent for possible RMM policies, equation (4) describes a single policy example (L1M2 in the Figure 9).

While the following equation shows the available budget for Policy$_i$:

$$AB_i = \int_0^t (BDI_i - BSR_i)\, dt$$

Equation (4)

Where:

Notation	Meaning	In Figure 9
AB_i	Available budget for Policy$_i$	*L1M2 Available Budget*
$\boldsymbol{BSR_i}$	Policy$_i$ budget spending rate (Outflow from the available budget for Policy$_i$)	*L1M2 Budget Spending Rate*

To accommodate for over spending situations, budget devoted to implementing Policy$_i$ (BSR_i) is controlled by a graph function shown below. The input to this graph function is the relative budget for Policy$_i$, which is the available budget of Policy$_i$ divided by the cost of implementating 1% of this policy. The model has normalized the policy implementation level from 0 to 100, being 0 not implemented policy and 100 fully implemented policy. However, the cost of implementing a policy differs from one policy to another. Accordingly, the model calculates the amount of budget spent implementing a policy to reach a 1% of implementation. If the value of this relative budget is more than 1, all requested spending on the policy is approved. However, if the value of this relative budget is to less than 1, the value of the graph function becomes a fraction choking the spending until reaching zero.

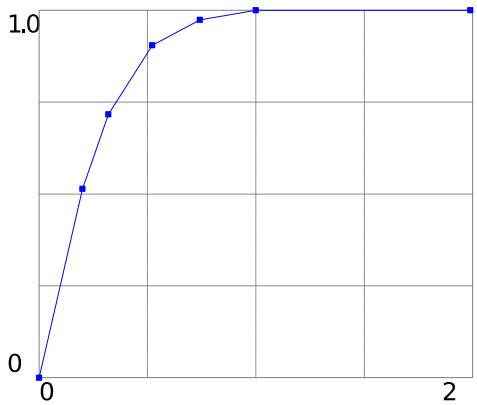

Figure 10 Graph lookup – L1M2 Effect of Budget on Expenditure

The value of the implementation level of Policy$_i$ controls the budget devoted to implementing Policy$_i$ (BSR_i) as well, so that this value does not exceed 100% or goes under 0%. Keeping the value of this level at 100% is tricky because of having an inflow and an outflow with implementation time and depletion time respectively. To fix this issue, we used the policy max implementation level to accommodate for depletion (MIL_i) which is defined as follows

$$MIL_i = 100 \cdot \frac{1 + IRT_i}{DRT_i}$$

Equation (5)

Where:

Notation	Meaning	In Figure 9
MIL_i	Policy$_i$ max implementation level to accommodate for depletion	*L1M2 Max Implementation Level Accommodate Depletion*
IRT_i	Policy$_i$ full implementation required time	*L1M2 Full Implementation Required Time*
$\boldsymbol{DRT_i}$	Policy$_i$ full depletion required time	*L1M2 Full Depletion Required Time*

The already used budget on implementing Policy$_i$ (UB_i) is defined as:

$$UB_i = \int_0^t BSR_i \, dt$$

Equation (6)

Where:

Notation	Meaning	In Figure 9
UB_i	Already used budget on implementing Policy$_i$	*L1M2 Used Budget*
$\boldsymbol{BSR_i}$	Policyi budget spending rate (Inflow to the already used budget on implementing Policy$_i$)	*L1M2 Budget Spending Rate*

While the already spent budget on all policies (SP) is defined as:

$$SP = \sum_{i=1}^{n} UB_i$$

Equation (7)

Where:

Notation	Meaning	In Figure 9
SP	Already spent budget on all policies	*Spent Budget*
$\boldsymbol{UB_i}$	Already used budget on implementing Policy$_i$	*L1M2 Used Budget*

4.1.5. RESILIENCE DIMENSIONS' LEVEL

The model contains four-dimension level indicators for each of the four dimensions of the RMM. The following graph shows the Leadership and Governance indicators as an example. The dimension indicator is a weighted average of the sub-dimensional indicators, while the sub-dimensional indicator is a weighted average of the effective policies implementation values of the policies under it. In the SD model, there is no reason to have different values for the weights of the policies or of the sub-dimensional indicators. However, in certain cases the policies under the same sub-dimension are not covering all SMART stages. In this case, we have to sum the weights of the empty stages with the intended ones following them so that the indicators have values that matches the policy stages representing them.

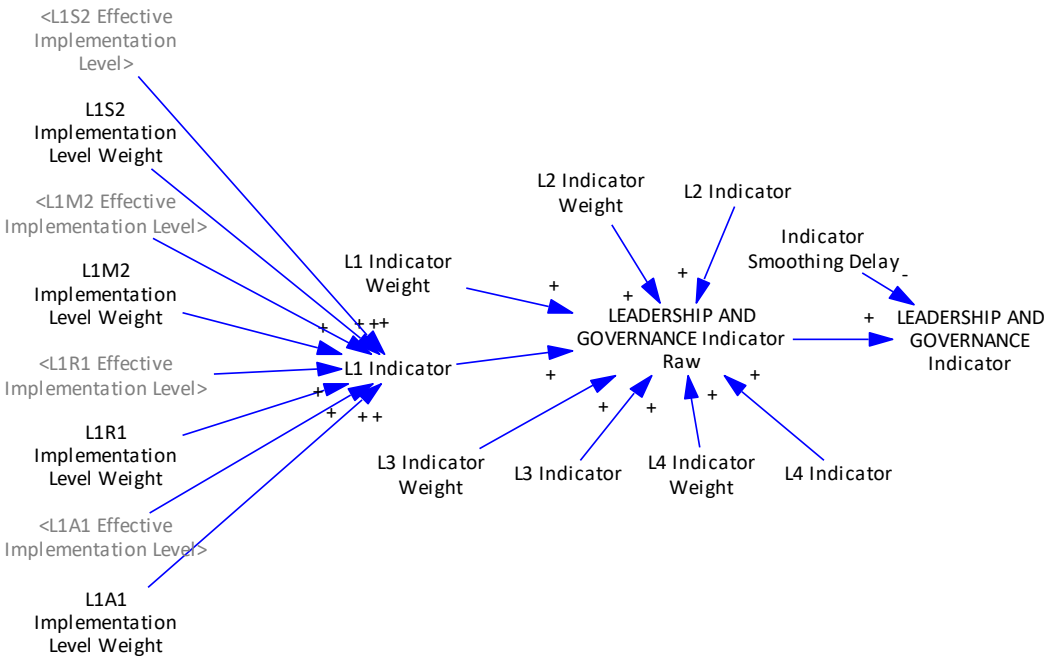

Figure 11: Indicator Sub Model with L1 Indicator as an Example

As an example of sub-dimension's indicators, $L1$ sub-dimension's indicator ($L1I$) is defined as:

$$L1I = \sum_{i=1}^{n} (IL1W_i \cdot EIL1_i)$$

Equation (8)

Where:

Notation	Meaning	In Figure 11
$L1I$	Indicator of sub-dimension $L1$	*L1 Indicator*
$IL1W_i$	Implementation Level Weight of Policy$_i$	*L1S2 Implementation Level Weight* *L1M2 Implementation Level Weight*

		L1R1 Implementation Level Weight *L1A1 Implementation Level Weight*
$\boldsymbol{EIL1_i}$	Effective Implementation Level of Policy$_i$	*L1S2 Effective Implementation Level* *L1M2 Effective Implementation Level* *L1R1 Effective Implementation Level* *L1A1 Effective Implementation Level*

In calculating the sub-dimension's indicators, we use the *Policy Effective Implementation Levels* (*EIL1*, *EIL2*, … *EILn*). If we take sub-dimensional indicators to be LS_1 , LS_2 … LS_n and their corresponding weights LSW_1 , LSW_2 … LSW_n. Then, the calculation for Leadership and Governance Indicator of the policy implementation can be defined as follows:

$$LGI = \sum_{i=1}^{n} (LSW_i \cdot LS_i)$$

Equation (9)

Where:

Notation	Meaning	In Figure 11
LGI	Leadership and Governance Indicator	Leadership and Governance Indicator Raw
LS_i	Indicator of the ith sub-dimension	*L1 Indicator* *L2 Indicator* *L3 Indicator* *L4 Indicator*
$\boldsymbol{LSW_i}$	Weight of the ith sub- dimension's indicator	*L1 Indicator Weight*

	L2 Indicator Weight
	L3 Indicator Weight
	L4 Indicator Weight

4.2. THE GRAPHICAL USER INTERFACE DESIGN

The CRD tool's Graphical User Interface (GUI) consists of three different views: *Initialization*, *Simulation*, and *Results*. Each of these views serves a different purpose. Figure 12 shows the features of these views.

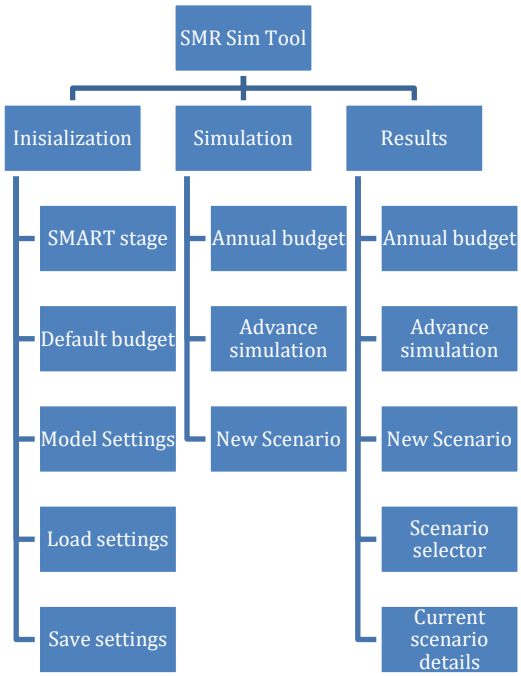

Figure 92 SMR Simulation Tool structure

4.2.1. INITIALIZATION VIEW

This view gives the user brief information about the SMR project and about the RMM. However, the main purpose of this view is to initialize the tool to suit the user's needs. Through this view the user can select one of the SMART stages for her/his city. In certain cases, the city might be in the middle of

implementing one or more of the RMM policies, or even in the middle of two maturity stages. Therefore, the tool also allows the user to select the implementation level of each RMM policy independently in a scale from 0 to 100 in order to particularize to their own city more precisely. For example, if a user perceives that the city is in the Moderate level, the model default setting will provide all policies within starting and moderate stages are fully in place (100%), which may not be completely true. In some cases, certain policies may have been in place, but not implemented fully (up to 100%). Or there are others which are not within the moderate stage but the city has already started to implement them partly. To make it more precise, the user can still adjust the default setting of each policy by modifying the implementation level of each policy from 0% to 100%.

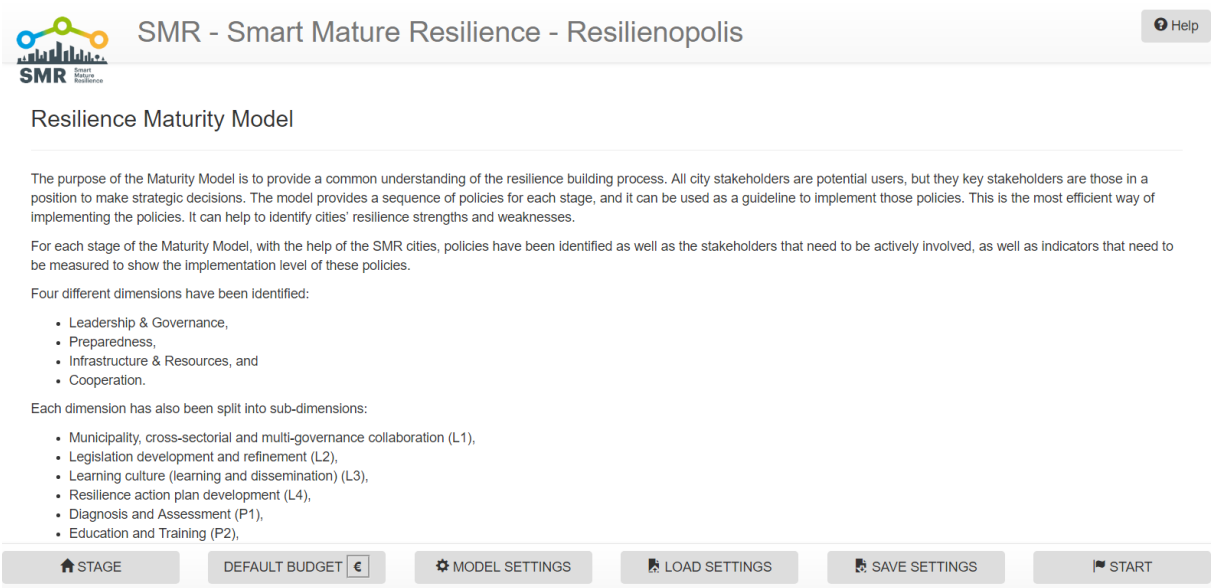

Figure 13 Initialization view

In the initialization view, the user can change certain CRD tool parameters so that the model can adjust better to the characteristics of her/his city case. The user can set the default annual budget devoted to the implementation of the RMM policies. In addition, the user can change the individual policy's implementation and depletion times as well as the implementation cost. Via this view, the user can change certain interface parameters as well. The user can change the default city name *Resilienopolis* to her/his city name. She/he can also change the currency units used in the model. Euros, Pounds Sterling, and Norwegian Kroners are possible choices.

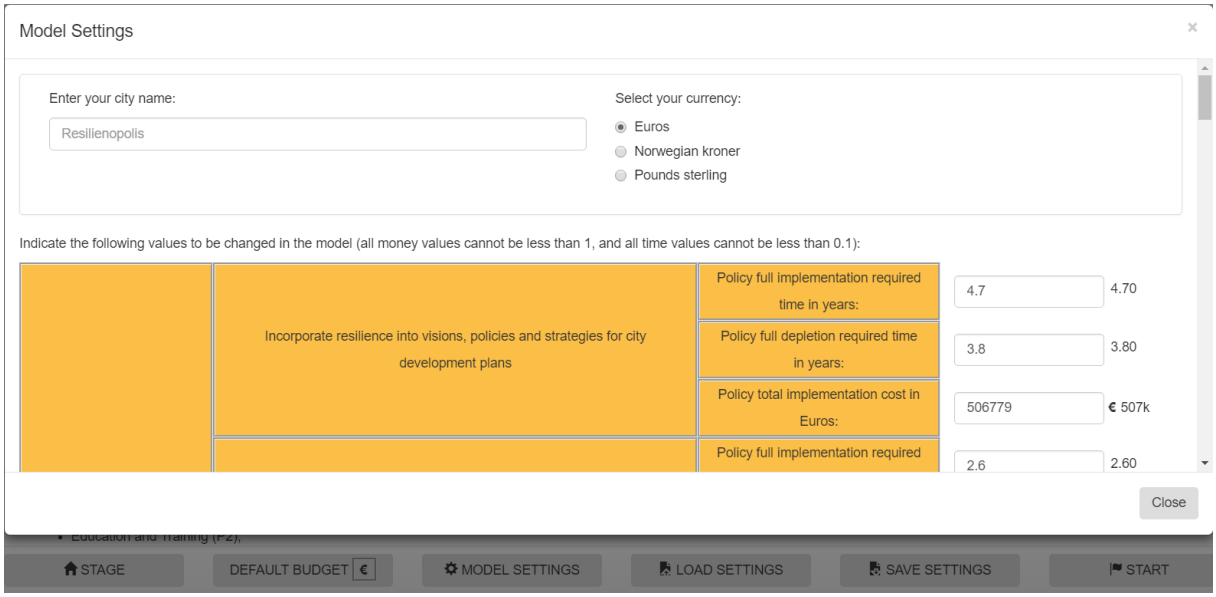

Figure 14 Settings inside the Initialization view

After setting all the initialization values in the initialization view, by using Save and Load model settings, the user can save and load all these values to a JavaScript Object Notation (JSON) file. This will save the effort needed to set these initial values every time the simulation tool is used.

4.2.2. DECISION VIEW

In the decision view, the user can enter the decisions related to spending on individual policies, and emulate budget increases or cuts. The SMR simulation tool enables the user to have multiple simulation scenarios to compare their results. The current simulation is the one which the user is currently entering decisions to. In the decision view, the user can advance the current simulation one year ahead to the future, otherwise reset this current simulation and start a new one.

The user can change her/his decisions of spending on individual policies every simulation time step, via textbox that is connected to each of the RMM policies included in the simulation tool. The textboxes are equipped with input checking algorithms that will prevent users from entering non-numerical values. All values entered to these textboxes are summed and subtracted from the current annual budget, so that the user can understand how much is the unbudgeted money left in the current simulation year. Textboxes values are not altered by advancing the simulation to the future, although still possible to be changed by the user from year to year.

In the decision view, the users can follow the current simulation year, the value of the current annual budget taking into consideration any budget increases or cuts, in addition to the unbudgeted money of this simulation year referred to above.

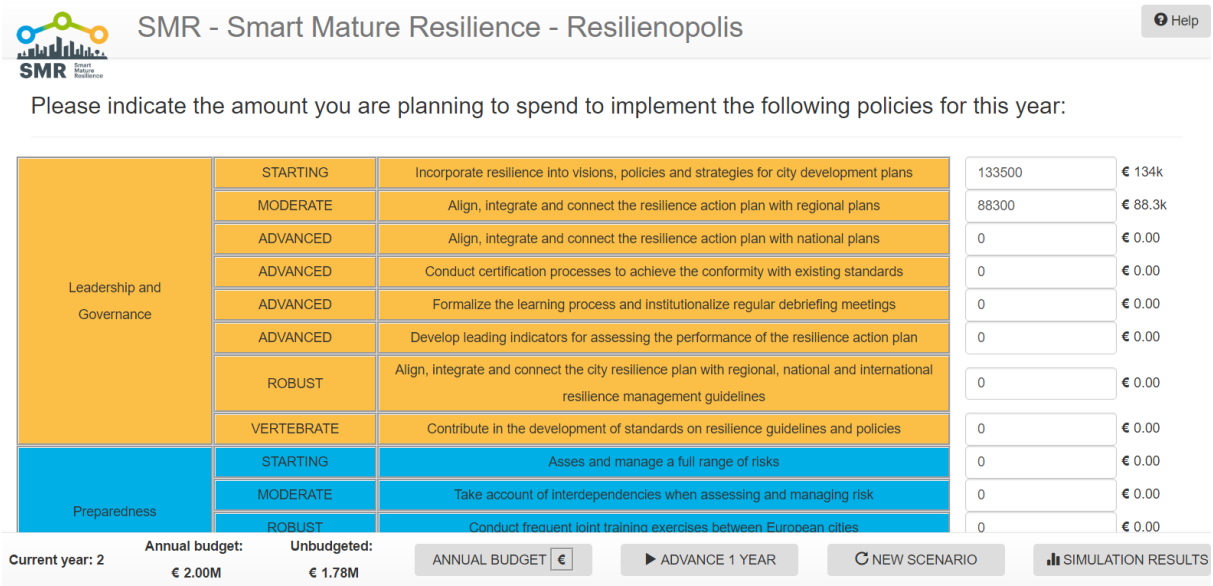

Figure 15 Simulation view

4.2.3. RESULTS VIEW

The results view shows the user all of the simulation outcomes she/he needs to know. For clarity, the simulation outcomes are organised by the RMM dimension. Using a set of four buttons, the user can change the dimension outcome shown in this view.

This view shows the budget devoted to every individual policy, and it shows the budget already spent on the implementation of this policy. In addition, the view shows the same mentioned budget numbers for the whole dimension. As mentioned earlier in the SD model design section, the user can spend money on one policy, and its implementation progresses, however this implementation values are not effective until all needed preceding policies have their implementation values reaching certain threshold values. Both values are shown on the interface per policy as pie charts.

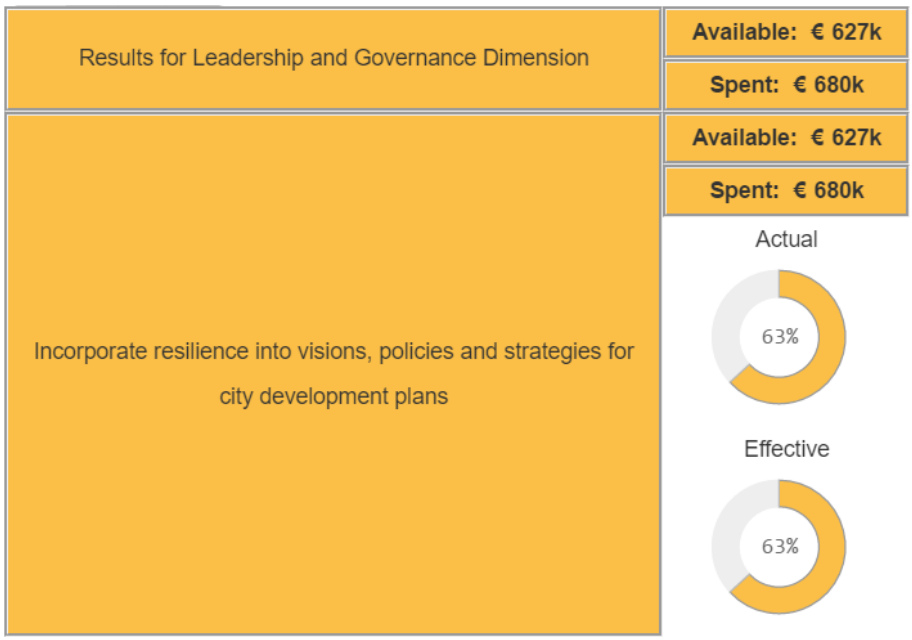

Figure 16 Result view's indicators

For the showed dimension, the results view shows the over-time progress of this dimension's indicator on a time-behaviour graph. This time-behaviour graph can show three different simulation scenarios. The simulation tool saves all simulated scenarios in the current web session, however only the last three are shown on the time-behaviour graphs to keep the graph clear. The following graphs are an example. The simulation tool allows the user to select the scenarios she/he is interested in showing on the time-behaviour graphs. The user can also change the scenario names into more expressing names, as well as scenario display colours.

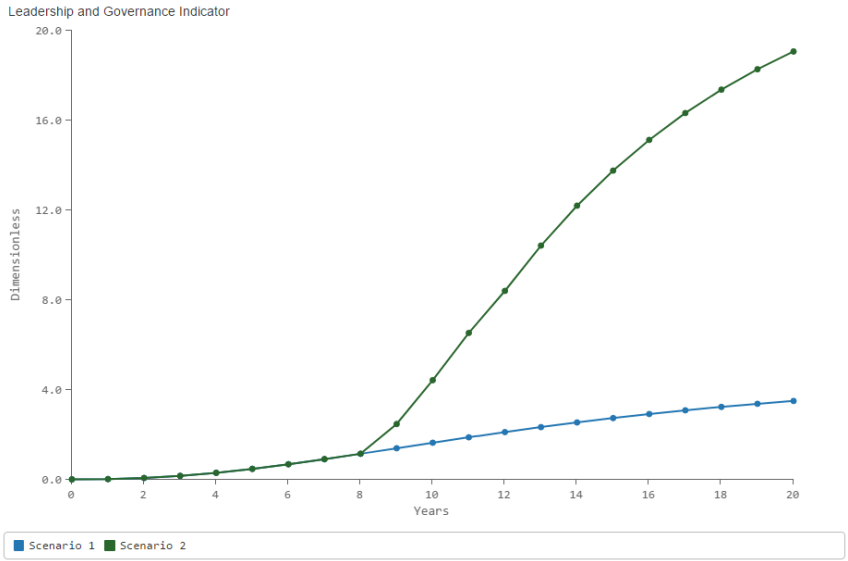

Figure 17 Result view's graph – Leadership and Governance level evolution over time

The simulation tool has a set of four power-meter gauges, one for each dimension. These power-meter gauges indicate the current SMART maturity stage per dimension. The following graph shows the leadership and governance dimension power-meter gauge.

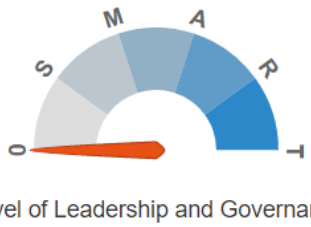

Figure 18 Result view's speedometer— Leadership and Governance

A time-behaviour graph shows the progress of summation of all policies' spent budgets. This graph will show this time-behaviour for the same selected three scenarios. The following graph is an example.

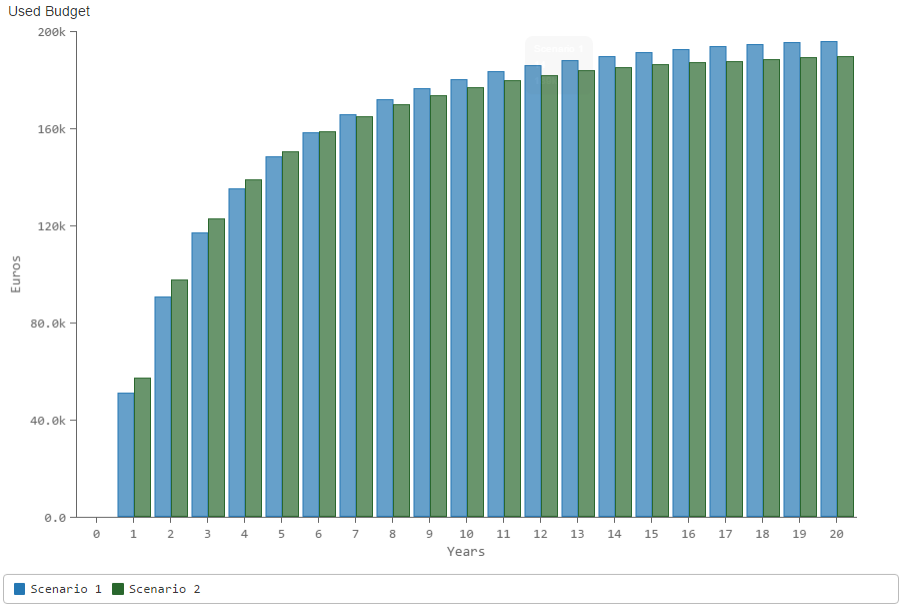

Figure 19 Result view's budget evolution over time graph

Every four years as part of thr simulation, the tool sends supporting messages to the user whenever she/he ignores the order of the RMM policies implementation (linear and transversal). These messages will be shown in the simulation and result view. The following graph shows an example of the messages. When the user hovers over any policy description in the message, the simulation tool highlights this policy in the current view. The messages are kept in the view until the user explicitly removes them by pressing their close buttons.

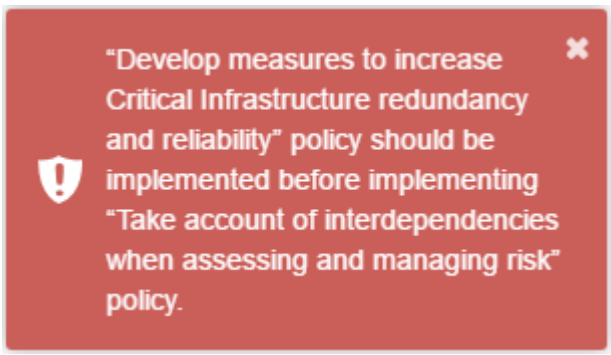

Figure 20 Pop-up message

From the results view, the user can view the current scenario details. Current scenario details view is a separate page that shows all annual spending decisions per policy taken by the user since the beginning of this scenario. It also shows the four dimensions' indicators on one time-behaviour graph. Two other time-behaviour graphs show the annual expenses and cumulative expenses per dimension. The following graph shows an example of this view.

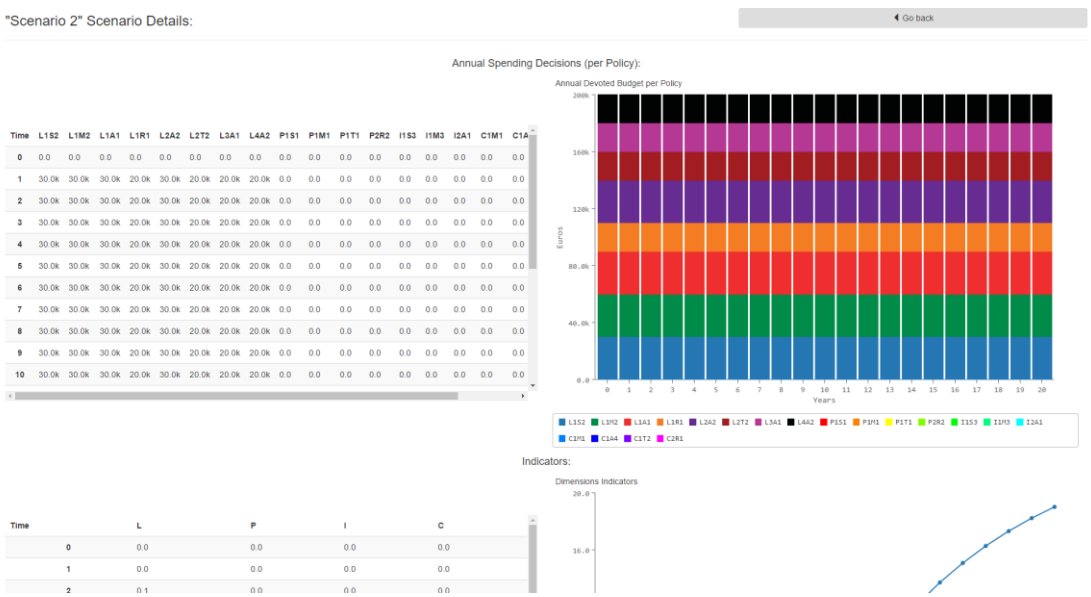

Figure 21 Current scenario details' graphs

5. PILOT TEST OF THE SIMULATION TOOL

To test and receive feedback about the final version of the simulation tool achieved after the two workshops, one-day pilot implementation sessions have been conducted in each of the Tier 1 cities: Donostia, Glasgow and Kristiansand. Relevant stakeholders took part during the three sessions who provided useful feedback and suggestions to improve the tool.

The three pilot implementations had the same objectives:

- Show the tool to different stakeholders of the tier 1 cities and explain its potential as a training tool for the resilience building process.
- Become familiarized with the features of the CRD tool.
- Identify the tool's potential and debate if it works as a training tool.
- Validate the tool.
- Suggest improvements.

To fulfil the objectives, first, a general presentation was carried to explain both the structure and functions of the tool. Then, the users were divided into small groups and were asked to play freely with the tool so that they got to know the CRD tool. Following, in the same groups, they were asked to play with the tool with the objective of achieving 100% of resilience level. To do so, participants were guided following 5 different steps. First, they were asked to calibrate the tool's parameters for their city, that is, to set the value of each parameter to an appropriate value for their city. Second, without using the tool, they had to design a strategy to obtain the highest resilience level and to consider the possible results. As part of this step, A3 size sheets of paper were distributed to the groups with the aim of facilitating the brainstorming process. Third, the groups were asked to apply the designed strategy on the tool and compare the obtained results with the ones they had originally considered. Fourth, they had to analyze and obtained conclusions about the deviation that might have happened between the foreseen results and the actual results. Finally, after playing with the tool and obtaining some conclusions, the participants were asked to answer a questionnaire composed of 18 questions related to the usability, the complexity and the suitability of the tool as a training tool (Annex 8). Apart from that some feedback comments were also written down. The main objective of the questionnaire was to receive feedback of potential users to identify possible weaknesses and improvements of the tool as a training tool. Table 2 summarizes the activities performed during the pilot test.

Annex 8 shows the questionnaire and the collected feedback.

Table 2: Exercises performed within the pilot test sessions

GOAL	DESCRIPTION OF EXERCISE
Get familiarized with the tool	**Exercise 1: Free play with the CRD tool** In this part, the participants were in general free to use the CRD tool as they wish, get familiar with the tool, its functionalities etc. They were also encouraged to pose questions to better understand the tool.
SIMULATION MODEL VALIDATION	**Exercise 2 – Part 1: Trying the CRD tool having a TARGET—Calibration** The exercise 2 target was: ''achieving 100% level on all 4 SMR dimensions' indicators with the lowest possible cost by the end of the 40 years simulation period''. The Part 1 target was: particularizing the parameters inside the tool to the city. In the first part of the exercise, participants calibrated the three parameters of the policies: cost, implementation time and depletion time. It was important to baer in mind that the parameter calibration took into account the characteristics of each city and that the introduced values were the base of the following simulation.
	Exercise 2 – Part 2: Trying the CRD tool having a TARGET – Strategy design The exercise 2 target was: ''achieving 100% level on all 4 SMR dimensions' indicators with the lowest possible cost by the end of the 40 years simulation period''.

The Part 2 target was: design a draft of a resilience building strategy before using the simulation tool.

Participants were asked to brainstorm possible strategies to achieve the target. In this part they did not use the simulation tool and hence, they needed to work with A3 papers and estimate the possible results after applying their strategy. It was important to realise this part of the exercise was the most complex one as depending the background of each participant the strategy could vary. Nevertheless, there was not a correct answer for this part as the objective was to make them brainstorm before the following parts.

Exercise 2 – Part 3: Trying the CRD tool having a TARGET – CRD tool results

The exercise 2 target was: ‘’achieving 100% level on all 4 SMR dimensions’ indicators with the lowest possible cost by the end of the 40 years simulation period’’.

The Part 3 target was: compare the CRD tool results with the ones in Exercise2-Part2

Participants simulated their designed strategies using the CRD tool and compared the obtained results with the ones they have foreseen in Part 2. In this part it was important to ensure the simulation tool was used correctly and that participants were introducing their strategies in the proper way.

Exercise 2 – Part 4: Trying the CRD tool having a TARGET – Conclusions

The exercise 2 target was: ‘’achieving 100% level on all 4 SMR dimensions’ indicators with the lowest possible cost by the end of the 40 years simulation period’’.

The Part 4 target was: get conclusions of the obtained results during the session.

The participants in a plenary mode discussed about the results they have obtained during the session. It was important to make them realise there is not a correct answer and that the CRD tool is not giving the final solution, yet it gets you closer to an effective resilience building process.

As result of the three pilot implementations, the CRD tool was evaluated by taking into account the following three main aspects: usability of the tool, the parametrization process and the tool's result.

On the one hand, regarding the usability of the tool, the overall result was that the CRD tool is easy and useful yet the applied concepts are too theoretical in some cases. Therefore, the CRD tool helped some of the users to understand better the resilience building process, even if they found it complicated.

On the other hand, concerning the parameter estimation process, participants agreed that was challenging to parametrice specific policies for each city. Nevertheless, they found it necessary to undertaken a parametrization process to understand the scope of the resilience building process and better define the scope of each policy.

Finally, regarding the CRD tool's results, participants were more skeptical. They stated that more time was needed to better understand the output of the tool as well as multidisciplinary groups to ensure information regarding all the boarded topics.

However, although the participants thought it was complex to understand the concepts of the tool, we need to take into account that for some of them, this was the first contact with the tool and they did not have much time to familiarise themselves with it and understand better its potential. This tool has been developed with the aim to be used regularly over longer periods of time and therefore, once a user is familiarized with it, it is expected that it will be easier for them to interpret and make use of the obtained results.

Apart from that, based on the made suggestions, some modifications were applied on the CRD tool (see suggestions on Annex 8). For instance, the suggestions concerning the tool being too abstract, theoretical or far-removed from the reality were managed by adding a "Help" button in the CRD tool that takes the user to a user-friendly handbook with basic instructions about how to use the tool. Apart from that a tutorial video was also uploaded to facilitate the comprehension of the CRD tool. Moreover, most of the participants agreed providing examples of how the CRD tool has been used in a city will

significantly promote the use of the tool, especially the first times. In this sense, all the data collected concerning the cities parametrizations made by the participants in the different workshops and pilot implementations have been stored for further use in future applications. Concerning the translation of the tool, even if it could meaningfully help, this suggestion was not considered especially because the Maturity Model is already translated to Spanish in the CWA 17301 and the codes of the policies are maintained what facilities the end-user to identify the policies. as it was not contemplated at the begging of the project and therefore it was out of scope. Finally, some suggestions were made regarding the design of the tool such as changing the location of the buttons. These suggestions were annotated yet not carried out because there was not consensus about this to be a problem.

6. CONCLUSIONS

The CRD tool is a web-based tool that helps cities to better understand how the resilience building process works and make explicit the consequences of the implemented strategies regarding the policy implementation. The basis of the CRD tool lies on the RMM tool. The policies defined in the CRD tool are the ones defined in the RMM. Furthermore, the CRD tool defines precedence relationships among the policies (linear and transversal relationships), since not all of the policies should be implemented at the same time neither in the same order. Some of the policies depend on the previous development of other policies and, therefore, if the predecessor policy is not implemented, the efficiency of the implemented policy is likely to be low. The CRD tool helps the user to understand these relationships by making them more explicit. As a consequence, the user can better understand the resilience building process and the unintended consequences that may occur if the policies are not implemented in the proper order. As the input variable, the user needs to decide how much budget will allocate to the development process of each policy. This will determine the resilience level achieved.

The CRD tool has been constructed for use at the strategic level, since the RMM policies have been defined from a holistic approach. The policies at operative level are not within the model and therefore, the tool is not suitable to use it at operational level. In addition to this, the precedence relationships among the RMM policies have been defined at a general level (taking into account the general definition of the RMM policies) and in case of the transversal relationships at a sub-dimension level, based on the definition of the sub-dimensions. Thus, it could occur that these relationships are not totally applicable in case of a particular city.

As a summary, the CRD tool complements the RMM tool since it helps the user to better understand the RMM and its functioning as well as to alert the user about the suitability of the taken decisions through the resilience level achieved at the end of the simulation. Apart from that it also helps to scale the magnitude of the resilience building process through the initial parametrization of the main variables of the tool (implementation cost of each policy, implementation time of each policy and depletion time of each policy). It also allows to learn how to use the resources efficiently in order to achieve high resilience level with a minimum amount of resources. Therefore, this tool is a support tool for the RMM and RBP tools since it allows the cities to learn more about how the resilience building process works and to train in order to be more effective in this process.

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ANNEX 1: STATE OF ART TABLES

Below, tables related to the state of the art where the three most used simulation tools are compared and described more in detail are presented.

Table 3: The SIMULATE checklist – adapted from [1] and text is quoted from [2]

	Problem requirement
System	"Modelling multiple events, relationships, and stakeholders representing the system processes."
Interactions	"Including nonlinear or spatial relationships among stakeholders and their context that influence behaviours and make outcomes in the system difficult to anticipate."
Multilevel	"Modelling a problem from strategic, tactical, or operational perspectives."
Understanding	"Modelling a complex problem to improve the system that cannot be solved analytically."
Loops	"Modelling feedback loops that change the behaviour of future interactions and the consequences for the system."
Agents	"Modelling multiple stakeholders with behavioural properties that interact and change the performance of the system."
Time	"Time-dependent and dynamic transitions in a system."
Emergence	"Considering the intended and unintended consequences of system interventions to address policy resistance and achieve target outcomes."

Table 4: SD, DES, and ABM Comparison—adapted from (Marshall, Burgos-Liz, IJzerman, Crown, et al., 2015b)

Aspect	SD	DES	ABM[3]
Type of problems	Strategic	"Operational, tactical"	"Strategic, operational, tactical"
Perspective	"System-oriented, emphasis on dynamic complexity (top–down)"	"Process-oriented, emphasis on detail complexity (top–down)"	"Individual-oriented, dynamic and detail complexity (bottom–up)"
Resolution	"Homogeneous entities, continuous policy pressures and emergent behavior"	"Individual heterogeneous passive entities, attributes, and events"	"Individual heterogeneous active agents, decision rules"
Origin of dynamics	"Deterministic endogenous fixed structure"	"Stochastic endogenous fixed processes"	"Agent–agent, agent–environment interactions and adaptive behavior of agents"
Handling of time	"Continuous"	"Discrete"	"Discrete"

Approach	“Exploratory and explanatory”	“Explanatory”	“Exploratory and explanatory”
Basic building blocks	“Feedback loops, stocks, and flows”	“Entities, events, queues”	“Autonomous agents, decision rules”
Data sources	“Broadly drawn: qualitative and quantitative”	“Numerical with some judgmental elements”	“Broadly drawn: qualitative and quantitative”
Data sources	“Broadly drawn: qualitative and quantitative”	“Numerical with some judgmental elements”	“Broadly drawn: qualitative and quantitative”
Unit of analysis	“Feedback loops and stocks’ dynamics”	“Queues, events”	“Decision rules, emergent behaviour”
Mathematical formulation	“Differential equations”	“Mathematically described with logic operators”	“Mathematically described with logic operators and decision rules”
Outputs	“Understanding of structural source of behavior modes, patterns, trends, relevant structures, aggregate key indicators”	“Point predictions, performance measures”	“Detailed and aggregate key indicators, understanding of emergence due to individual behavior, point predictions”
Model maintenance	“Upkeep may require large structure modifications, global”	“Upkeep may require process modifications, global. Allows for local	“Upkeep may require simple local modifications”

		modifications regarding individual heterogeneity”	

Table 5: Purpose ("What is the purpose of the model?") – adapted from (Marshall, Burgos-Liz, IJzerman, Crown, et al., 2015b)

Purpose	SD	DES	ABM
Deterministic	Yes		
Engaging stakeholders	Yes		
Relevance of patterns and/or aggregate values	Yes		Yes
Strategic level problem	Yes		Yes
Workflow queues and wait times are a big concern		Yes	
Capture heterogeneity		Yes	Yes
Importance of tracking individual behaviour		Yes	Yes
Tactical level problem		Yes	Yes
Operational level problem		Yes	Yes
Relevance of agent-agent and agent-environment interactions			Yes

Table 6: Object ("What is the scope of the model (boundary)?") – adapted from (Marshall, Burgos-Liz, IJzerman, Crown, et al., 2015b)

Object	SD	DES	ABM
Population size scalability	Yes		
More accessible skill set	Yes		
Aggregate level data	Yes		Yes
Quick construction	Yes		Yes
Flexibility		Yes	Yes
Heterogeneity scalability		Yes	Yes
Individual level data		Yes	Yes
Agency/human choice adaptability		Yes	Yes
Dynamics across networks		Yes	Yes

ANNEX 2: COMMENTS GATHERED FROM WORSKHOP IN DONOSTIA

The received feedback comments were classified depending on whether the comment was related to the System Dynamics model or the Graphical User Interface.

The SD Model design

Users found the results given by the model were coherent, yet some could be more realistic. In the following list, the most highlighted comments and suggestions are presented:

1. The CRD tool defines the implementation level of a policy through a percentage applied by the user. However, participants pointed it would be more realistic to calculate the implementation level of a policy deciding the amount of resources the user wants to invest in each policy.

2. Regarding policy cost, the preliminary version assumed all the policies cost the same. Nevertheless, the participants said it was not realistic to be so, each policy should have different unitary cost and their maintenance should be different too.

3. The CRD tool defines the available budget from the beginning, and they pointed out it was not a realistic situation, since the available budget might change from year to year. Therefore, they suggested having a standard annual budget which could be defined by the user at the beginning and also have the opportunity to change it in the middle of the game to represent budget cuts.

4. The CRD tool is based on policies' relationships which are defined with the same weight and importance. Participants suggested that to be more realistic, both linear and transversal relationships should have stronger or weaker relationships for each case and be more or less important to achieve resilience.

Once the suggestions were discussed, the 1st and 3rd comments were implemented in the updated version of the model. For the cases of the 2nd and 4th suggestions, two questionnaires were carried out in order to parameterize the values of the model.

Therefore, the updated version of the model changes the percentages of implementation level to budget allocated to each policy, the available budget can be fixed during the simulation and the user has the possibility to particularize the cost of the policy to any city.

The Graphical User Interface

In general, participants found the GUI visually easy to understand, yet not so intuitive. In the following list, the most highlighted comments and suggestions are presented:

1. In the GUI, only the names of the policies were shown, yet they were not defined. The participants suggested a brief explanation of the policy should appear when the mouse hovers over the policy name. This should help a user to better understand what he/she is implementing.

2. The policies in the GUI were classified only depending on their resilience dimension. However, the participants also asked to sort them depending on the maturity stage to facilitate understanding the implementation order.

3. The resulting graphs and percentages were just defined in the model's user guide. The participants suggested adding a brief explanation of the meaning of these graphs and percentages which appear when the mouse hovers over these elements.

4. When defining the initial situation of the city in the Initial view, the participants were confused, as they thought they were already doing the simulation. Therefore, they asked to differentiate more clearly when the user is defining the initial state and when the simulation starts.

5. Related to the indicators, they commented that the actual indicators were useful, yet the evolution of the spent money should also appear as a result. They suggested adding both a general behaviour-over-time graph with the evolution of the total budget and a specific graph with the budget spent on each resilience dimension as well.

6. In general, the comments related to the feedback messages were positive. However, a group of the participants found the messages to be too long to read comfortably. This group suggested highlighting the policies appearing in the feedback messages in the decisions-screen to easily identify them.

7. Considering that the participants were using was a preliminary version of the CRD tool, they suggested that the updated version should give them the opportunity to save the obtained results and be able to share them with colleagues.

After analysing the suggestions, some decisions were taken. For the suggestions 1, 2, 3, 5 and 6 the comments of the participants were implemented in the updated version of the model. In the case of suggestion 4, a third screen with a brief explanation of the model has been designed which appears at the beginning of the simulation. Finally, for the 7th suggestion, the updated version not only enables to save the results but to download them and send them to any other player.

Therefore, the updated version of the model included brief definitions of the policies, buttons and graphs which appear when the mouse hovers over them. Also, the policies were classified depending on the maturity model and were highlighted when referred on a pop up message. Apart from that, new graphs related to the budget evolution over time were added, as well as an initial step with an initial view in order to initialise the simulation.

ANNEX 3: QUESTIONNAIRE FOR THE TRANSVERSAL RELATIONSHIPS

The questionnaire sent to the SMR city partners is presented below.

Questionnaire

The aim of the questionnaire is to validate the following precedence relationships among the sub-dimensions defined in the maturity model. These precedence relationships mean that to fulfil one policy, it is necessary to have implemented the predecessor one. In total, we have identified 11 precedence relationships. Now, the aim is to validate these relationships.

Through this questionnaire, we would like you to answer to what extent from 0 to 5 (0 being not agree at all and 5 fully agree) you agree with the following predecessor relationships. Figure 21 represents these relationships in a diagram. The number of the question is related to the number of the relationship in the diagram.

1. Legislation development and refinement (L2) refer to the law requirements and systematization processes required by external entities. These external requirements foster the resilience building process of the cities. Therefore, we consider that having legal requirements about improving the resilience of the cities (L2) is necessary for the development and implementation of the resilience action plan (L4).

To what extent do you agree with the above statement?

Not agree at all **Fully agree**

0 ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐

Comments:

2. The resilience action plan is the document in which we define all the activities, actions, and milestones that are necessary to implement in order to build the resilience of the cities. This is the base for all the activities related to the resilience building process. Therefore, having well defined, developed and implemented resilience action plan (L4) is necessary for incorporating resilience into city strategies and to align, integrate and connect the city resilience plan with regional, national and international resilience plans (L1).

To what extent do you agree with the above statement?

Not agree at all						Fully agree
0	1	2	3	4	5	

Comments:

3. Furthermore, having well defined, developed and implemented resilience action plan (L4) is also necessary for promoting a culture of resilience within the city and formalizing and systematizing the learning process (L3).

To what extent do you agree with the above statement?

Not agree at all						Fully agree
0	1	2	3	4	5	

Comments:

4. Furthermore, it is important to previously have well defined and implemented resilience action plan (L4) in order to allocate resources for resilience building processes (I2).

To what extent do you agree with the above statement?

Not agree at all **Fully agree**

0 ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐

Comments:

5. In turn, having resources allocated to build up resilience and to response (I2) is essential in order to be able to improve the reliability and safety of the CIs (I1). Resources are necessary to buy safer systems, renew the old physical systems for better and more reliable ones, have well maintained systems, carry out audits and therefore, it is important that resources are allocated to these activities.

To what extent do you agree with the above statement?

Not agree at all **Fully agree**

0 ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐

Comments:

6. The resilience action plan (L4) also allows in the diagnosis and assessment process (P1). Assessing the full range of risks is important to be able to manage them effectively. Moreover, taking account of the interdependencies among critical infrastructures and using risk systemicity questionnaire to assess and manage risks is essential to forecast cascading effects from disruptions.

To what extent do you agree with the above statement?

Not agree at all Fully agree

0 ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐

Comments:

7. In turn, assessing and managing risks properly (P1) is necessary to have more reliable and secure infrastructures (I1). Having analyzed what kind of risks can occur and how these risks can spread through different critical infrastructures, is important in order to improve the reliability of the infrastructure and be able to withstand short and long term stresses.

To what extent do you agree with the above statement?

Not agree at all Fully agree

0 ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐

Comments:

8. Having well defined and implemented resilience action plan (L4) is essential to promote partnerships among the city stakeholders and how they can collaborate and communicate with each other (C1).

To what extent do you agree with the above statement?

Not agree at all Fully agree

0 ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐

Comments:

9. In turn, these partnerships among the city stakeholders (C1) are mandatory to improve the education and training of the different city agents (P2). In order to improve the education and training, the participation and involvement of the different stakeholders are vital and help to enhance the coordination of all the involved stakeholders.

To what extent do you agree with the above statement?

Not agree at all										Fully agree
0	☐	1	☐	2	☐	3	☐	4	☐	5 ☐

Comments:

10. The resilience action plan (L4) also establishes how the city should be involved and participate in the city resilience networks (C2).

To what extent do you agree with the above statement?

Not agree at all										Fully agree
0	☐	1	☐	2	☐	3	☐	4	☐	5 ☐

Comments:

11. The participation in different city resilience networks (C2) is required to improve the education and training of the stakeholders (P2) since they can learn from other cities and apply best practices obtained from other cities in their cities to improve their response capacity.

To what extent do you agree with the above statement?

Not agree at all Fully agree

0 ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐

Comments:

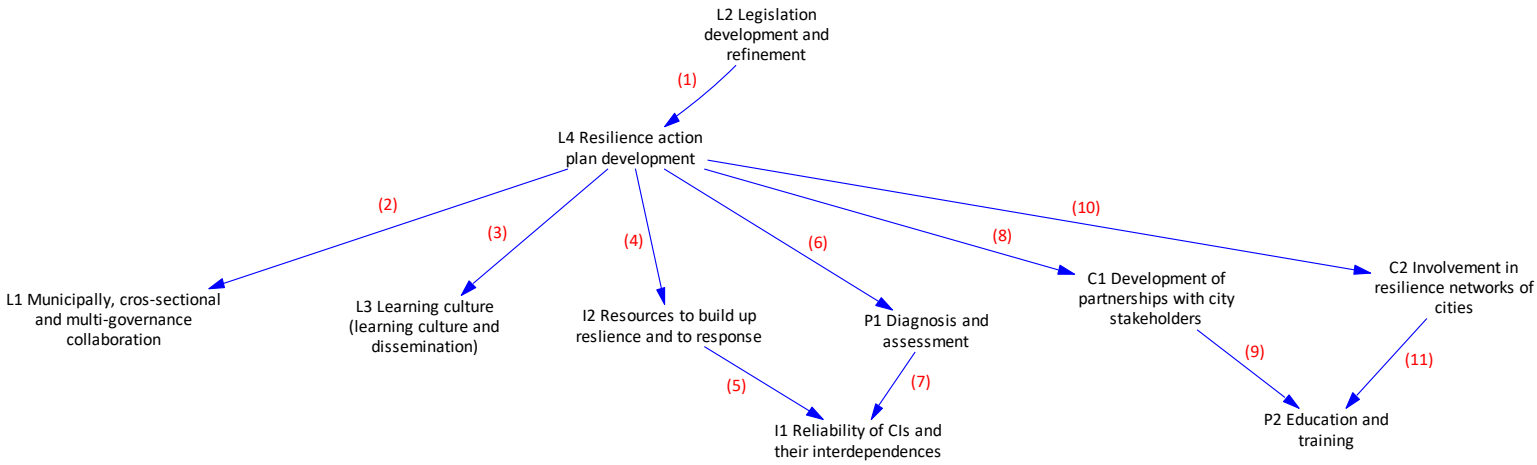


Figure 10 Transversal Relationships' diagram

The results obtained from the questionnaire are summarized in the Table below:

Table 7 Questionnaire results

CITY	Qu.1	Qu.2	Qu.3	Qu.4	Qu.5	Qu.6	Qu.7	Qu.8	Qu.9	Qu.10	Qu.11
Kristiansand	4	1	4	4	5	3	5	1	5	4	3
Donostia	2	1	2	2	3	3	4	2	3	2	3
Rome	1	4	2	2	1	4	4	3	4	4	4
Vejle	4	4	4	2	3	4	4	5	4	3	3
Glasgow	2	3	3	4	5	3	4	4	5	4	5
Riga	4	5	5	5	4	4	5	5	5	4	5
Lucy	3	1	4	3	2	2	4	1	4	3	4
AVERAGE	**2.85**	**2.71**	**3.43**	**3.14**	**3.29**	**3.29**	**4.29**	**3**	**4.29**	**3.43**	**3.86**

In order to analyse the results and decide whether a relationship exists or not, the criteria summarized in Table 8 was used. If the mean value was within the range of values between 3,1 and 5, then we considered there was a strong relationship. If the mean value was within the range of values between 2,8 and 3, then we considered there was a weak relationship. Finally, if the mean value was under 2.7, then we considered there was not any relationship.

Table 8: Criteria used to analyse the results

Mean value	Decision
3,1 - 5	A strong relationship exists
2,8 – 3,1	A weak relationship exists
0 - 2,8	There is not relationship

Based on this criteria, we defined which relationships were accepted and which ones were not. The only relationship that we rejected was the relationship defined in the second question. Most of the cities did not agree with this relationship and therefore we decided to reject it. Figure 21 shows the diagram with the definitive transversal relationships. The strong relationships are represented with a continue line, and the weak relationships with a dash line.

ANNEX 4: COMMENTS GATHERED FROM WORSKHOP IN GLASGOW

The received feedback comments were classified depending on whether the comment was related to the SD model or the Graphical User Interface.

The SD Model design

In general, the received comments pointed the updated version of the model was better than the one presented in Donostia. However, some improvements were suggested. In the following list, the most highlighted comments and suggestions are presented:

1. Regarding the currency used in the model, the participants suggested the currency could be adaptable to others such as pounds or Norwegian kroners as not all the cities are familiar with euros.

2. In general, they considered a 19 policy version was okay and 98 policy version model would be overwhelming. However, they suggested a larger version with 40 policies could be interesting to get a wider perspective of the resilience building process.

3. Implementing budget is okay, but not having the possibility to save it after taking the time of deciding were to allocated felt frustrating. Therefore, it should be interesting to be able to safe all the made movements.

4. They found really useful about being able to change the cost of the policies and the implementation and depletion times. And to safe the settings and be able to reload them.

5. City representatives believe that maintaining a policy should not cost that much – they disagree with the thought "you can't be a resilient city unless you constantly spend money"
    a. They agreed upon the following thought: Once the investment is done a city has to keep the policy in mind – maybe they don’t spend much money after implementing it, but they have to keep disseminating it.

Once the suggestions were discussed, both of them were taken into account for the final version of the model. On the one hand, on the latest version the user is able to set the currency in the initialization view. On the other hand, an extended version of the model has been modeled with 45 policies.

The Graphical User Interface

Participants found the updated version of the Graphical User Interface was better than the first one used in Donostia. They stated that thanks to the made improvements the Graphical User Interface was now more intuitive to use. However, they did suggest to add a column with the stablished costs of each policy in the simulation view to bare in mind when taking decisions. Yet this improvement has not been taken into account for the final version as there would be too much information and it could be overwhelming.

ANNEX 5: QUESTIONNAIRE FOR THE SIMULATION TOOL'S REQUIREMENTS

The questionnaire carried out during the workshop of Glasgow regarding the SMR simulation tool's requirements is presented below as well as the comments and the obtained results.

Questionnaire

1-Do you think the presented requirements are enough or do you consider that the tool should fulfil any other requirement?

Yes ☐ No ☐

Additional requirements:

- To be more accessible and user friendly: visual design + tutorial
- Clarify the purpose: training or "live" tool
- Ensure simplicity of functionalities
- Make it more visual, it is a game not an analysis tool

2-Regarding the first requirement "Holistic perspective" do you think this requirement is fulfilled taking into account the current functioning of the tool? Can you give some evidence about in which way this requirement is being fulfilled?

Yes ☐ No ☐

Evidence:

- 19 out of 98 policies
- Better than the Rockefeller tools

- It makes all the department realize about resilience.

3-Regarding the second requirement "Temporal order between policies" do you think this requirement is fulfilled taking into account the current functioning of the tool? Can you give some evidence about in which way this requirement is being fulfilled?

Yes ☐ No ☐

Evidence:

4-Regarding the second requirement "Relationships between policies" do you think this requirement is fulfilled taking into account the current functioning of the tool? Can you give some evidence about in which way this requirement is being fulfilled?

Yes ☐ No ☐

Evidence:

- Visual design to help the user know the order of implementation.
- Guide to use the tool and maybe a video tutorial
- Cities do not need to fulfill all policies -- in the end it is an inspiration tool

5-Regarding the second requirement "Trustworthy" do you think this requirement is fulfilled taking into account the current functioning of the tool? Can you give some evidence about in which way this requirement is being fulfilled?

Yes ☐ No ☐

Evidence:

- Transparency of the game → clear and coherent results

- The qualitative results help. Because quantitative results make the user to do more questions and doubt more about the model.

6-Regarding the second requirement " Flexible" do you think this requirement is fulfilled taking into account the current functioning of the tool? Can you give some evidence about in which way this requirement is being fulfilled?

Yes ☐ No ☐

Evidence:

- How to make new policies?

- Parametrize the values + budget adaptation

- They do not see if the new possibility to simulate unknown situation could be usable

Table 9 Results of the Requirement Questionnaire

	YES	NO
Q1	0	4
Q2	1	3
Q3	4	0
Q4	4	0
Q5	4	0
Q6	3	1

As an overall conclusion after the questionnaire, we realized that the defined requirements were not enough to ensure the validity of the simulation tool (Q1). The usability and the visibility of the tool's functions should be clarified in the updated version. Apart from that, the results of Q2 made us conclude 19 policies were not enough in order to achieve a holistic perspective, as a consequence a more extended version of the tool has been designed with 45 policies. Additionally, as resumed in Table 9, the rest of the requirements has been fulfilled.

ANNEX 6: PARAMETER ESTIMATION QUESTIONNAIRE

The following questionnaire was carried out in the Tier1 and Tier2 cities of the project after the Workshop in Glasgow, namely: Kristiansand, Donosti, Rome, Vejle, Glasgow, Riga and Bristol. After using the simulation tool and receiving feedback, the participants were asked to answer three questions for each policy of the simulation tool. The main objective with this questionnaire is to parametrize the initial values of the policies applied in the simulation tool. In order to do so, the formulated three questions ask about the implementation value, the needed implementation time and the depletion time. The questionnaire is organized maintaining the structure of the Resilience Maturity Model.

CRD tool Parameter Estimation **Please choose the estimate that best fits your city:**
LEADERSHIP AND GOVERNANCE
(L1) Municipality, cross-sectorial and multi-governance collaboration
Policy: (L1S2) Integrate the resilience into visions, policies and strategies for city development plans
In general, implementing policies imposes costs on cities, what do you think the average spending of your city will be to fully implement the L1S2 policy?
☐ 10,000 Euros ☐ 50,000 Euros ☐ 100,000 Euros ☐ 500,000 Euros ☐ 1,000,000 Euros
Policies require time to be implemented, what do you think the average L1S2 full implementation required time in years will be in your city?
☐ 1 year ☐ 3 years ☐ 5 years ☐ 10 years
Several policies if not maintained or updated at all, will have their implementation obsolete and becomes as never been implemented before at certain point of time. In your city, what do you think the L1S2 average full depletion time in years will be if not maintained at all?
☐ 1 year ☐ 3 years ☐ 5 years ☐ 10 years

Policy: (L1M1) Establish a resilience department or committee and a cross departmental coordination board and procedures
In general, implementing policies imposes costs on cities, what do you think the average spending of your city will be to fully implement the L1M1 policy?
☐ 10,000 Euros ☐ 50,000 Euros ☐ 100,000 Euros ☐ 500,000 Euros ☐ 1,000,000 Euros
Policies require time to be implemented, what do you think the average L1M1 full implementation required time in years will be in your city?
☐ 1 year ☐ 3 years ☐ 5 years ☐ 10 years
Several policies if not maintained or updated at all, will have their implementation obsolete and becomes as never been implemented before at certain point of time. In your city, what do you think the L1M1 average full depletion time in years will be if not maintained at all?
☐ 1 year ☐ 3 years ☐ 5 years ☐ 10 years
Policy: (L1M3) Adopt climate change preventive actions
In general, implementing policies imposes costs on cities, what do you think the average spending of your city will be to fully implement the L1M3 policy?
☐ 10,000 Euros ☐ 50,000 Euros ☐ 100,000 Euros ☐ 500,000 Euros ☐ 1,000,000 Euros
Policies require time to be implemented, what do you think the average L1M3 full implementation required time in years will be in your city?
☐ 1 year ☐ 3 years ☐ 5 years ☐ 10 years
Several policies if not maintained or updated at all, will have their implementation obsolete and becomes as never been implemented before at certain point of time. In your city, what do you think the L1M3 average full depletion time in years will be if not maintained at all?
☐ 1 year ☐ 3 years ☐ 5 years ☐ 10 years
Policy: (L1M4) Promote equality of access to services and basic infrastructure to vulnerable sector of society
In general, implementing policies imposes costs on cities, what do you think the average spending of your city will be to fully implement the L1M4 policy?
☐ 10,000 Euros ☐ 50,000 Euros ☐ 100,000 Euros ☐ 500,000 Euros ☐ 1,000,000 Euros

Policies require time to be implemented, what do you think the average L1M4 full implementation required time in years will be in your city?
☐ 1 year ☐ 3 years ☐ 5 years ☐ 10 years
Several policies if not maintained or updated at all, will have their implementation obsolete and becomes as never been implemented before at certain point of time. In your city, what do you think the L1M4 average full depletion time in years will be if not maintained at all?
☐ 1 year ☐ 3 years ☐ 5 years ☐ 10 years
Policy: (L1R1) Align, integrate and connect the city resilience plan with regional, national and international resilience management guidelines
In general, implementing policies imposes costs on cities, what do you think the average spending of your city will be to fully implement the L1R1 policy?
☐ 10,000 Euros ☐ 50,000 Euros ☐ 100,000 Euros ☐ 500,000 Euros ☐ 1,000,000 Euros
Policies require time to be implemented, what do you think the average L1R1 full implementation required time in years will be in your city?
☐ 1 year ☐ 3 years ☐ 5 years ☐ 10 years
Several policies if not maintained or updated at all, will have their implementation obsolete and becomes as never been implemented before at certain point of time. In your city, what do you think the L1R1 average full depletion time in years will be if not maintained at all?
☐ 1 year ☐ 3 years ☐ 5 years ☐ 10 years
(L2) Legislation development and refinement
Policy: (L2A1) Conduct certification processes to achieve the conformity with existing standards
In general, implementing policies imposes costs on cities, what do you think the average spending of your city will be to fully implement the L2A1 policy?
☐ 10,000 Euros ☐ 50,000 Euros ☐ 100,000 Euros ☐ 500,000 Euros ☐ 1,000,000 Euros
Policies require time to be implemented, what do you think the average L2A1 full implementation required time in years will be in your city?
☐ 1 year ☐ 3 years ☐ 5 years ☐ 10 years

Several policies if not maintained or updated at all, will have their implementation obsolete and becomes as never been implemented before at certain point of time. In your city, what do you think the L2A1 average full depletion time in years will be if not maintained at all?
☐ 1 year ☐ 3 years ☐ 5 years ☐ 10 years
Policy: (L2T1) Contribute in the development of standards on resilience guidelines and policies
In general, implementing policies imposes costs on cities, what do you think the average spending of your city will be to fully implement the L2T1 policy?
☐ 10,000 Euros ☐ 50,000 Euros ☐ 100,000 Euros ☐ 500,000 Euros ☐ 1,000,000 Euros
Policies require time to be implemented, what do you think the average L2T1 full implementation required time in years will be in your city?
☐ 1 year ☐ 3 years ☐ 5 years ☐ 10 years
Several policies if not maintained or updated at all, will have their implementation obsolete and becomes as never been implemented before at certain point of time. In your city, what do you think the L2T1 average full depletion time in years will be if not maintained at all?
☐ 1 year ☐ 3 years ☐ 5 years ☐ 10 years
(L3) Learning culture (learning and dissemination)
Policy: (L3M1) Promote a culture of resilience
In general, implementing policies imposes costs on cities, what do you think the average spending of your city will be to fully implement the L3M1 policy?
☐ 10,000 Euros ☐ 50,000 Euros ☐ 100,000 Euros ☐ 500,000 Euros ☐ 1,000,000 Euros
Policies require time to be implemented, what do you think the average L3M1 full implementation required time in years will be in your city?
☐ 1 year ☐ 3 years ☐ 5 years ☐ 10 years
Several policies if not maintained or updated at all, will have their implementation obsolete and becomes as never been implemented before at certain point of time. In your city, what do you think the L3M1 average full depletion time in years will be if not maintained at all?
☐ 1 year ☐ 3 years ☐ 5 years ☐ 10 years

Policy: (L3A1) Formalize the learning process and institutionalize regular debriefing meetings
In general, implementing policies imposes costs on cities, what do you think the average spending of your city will be to fully implement the L3A1 policy?
☐ 10,000 Euros ☐ 50,000 Euros ☐ 100,000 Euros ☐ 500,000 Euros ☐ 1,000,000 Euros
Policies require time to be implemented, what do you think the average L3A1 full implementation required time in years will be in your city?
☐ 1 year ☐ 3 years ☐ 5 years ☐ 10 years
Several policies if not maintained or updated at all, will have their implementation obsolete and becomes as never been implemented before at certain point of time. In your city, what do you think the L3A1 average full depletion time in years will be if not maintained at all?
☐ 1 year ☐ 3 years ☐ 5 years ☐ 10 years
Policy: (L3T2) Promote leadership for knowledge transferring and sharing among global cities, regions and nations
In general, implementing policies imposes costs on cities, what do you think the average spending of your city will be to fully implement the L3T2 policy?
☐ 10,000 Euros ☐ 50,000 Euros ☐ 100,000 Euros ☐ 500,000 Euros ☐ 1,000,000 Euros
Policies require time to be implemented, what do you think the average L3T2 full implementation required time in years will be in your city?
☐ 1 year ☐ 3 years ☐ 5 years ☐ 10 years
Several policies if not maintained or updated at all, will have their implementation obsolete and becomes as never been implemented before at certain point of time. In your city, what do you think the L3T2 average full depletion time in years will be if not maintained at all?
☐ 1 year ☐ 3 years ☐ 5 years ☐ 10 years

(L4) Resilience action plan development
Policy: (L4M1) Develop a resilience action plan to respond to shocks and long term stresses
In general, implementing policies imposes costs on cities, what do you think the average spending of your city will be to fully implement the L4M1 policy?
☐ 10,000 Euros ☐ 50,000 Euros ☐ 100,000 Euros ☐ 500,000 Euros ☐ 1,000,000 Euros
Policies require time to be implemented, what do you think the average L4M1 full implementation required time in years will be in your city?
☐ 1 year ☐ 3 years ☐ 5 years ☐ 10 years
Several policies if not maintained or updated at all, will have their implementation obsolete and becomes as never been implemented before at certain point of time. In your city, what do you think the L4M1 average full depletion time in years will be if not maintained at all?
☐ 1 year ☐ 3 years ☐ 5 years ☐ 10 years
Policy: (L4R1) Assess and monitor the efficiency of the resilience action plan periodically in order to improve it continuously
In general, implementing policies imposes costs on cities, what do you think the average spending of your city will be to fully implement the L4R1 policy?
☐ 10,000 Euros ☐ 50,000 Euros ☐ 100,000 Euros ☐ 500,000 Euros ☐ 1,000,000 Euros
Policies require time to be implemented, what do you think the average L4R1 full implementation required time in years will be in your city?
☐ 1 year ☐ 3 years ☐ 5 years ☐ 10 years
Several policies if not maintained or updated at all, will have their implementation obsolete and becomes as never been implemented before at certain point of time. In your city, what do you think the L4R1 average full depletion time in years will be if not maintained at all?
☐ 1 year ☐ 3 years ☐ 5 years ☐ 10 years

PREPAREDNESS
(P1) Diagnosis and Assessment
Policy: (P1S1) Assess and manage a full range of risks
In general, implementing policies imposes costs on cities, what do you think the average spending of your city will be to fully implement the P1S1 policy?
☐ 10,000 Euros ☐ 50,000 Euros ☐ 100,000 Euros ☐ 500,000 Euros ☐ 1,000,000 Euros
Policies require time to be implemented, what do you think the average P1S1 full implementation required time in years will be in your city?
☐ 1 year ☐ 3 years ☐ 5 years ☐ 10 years
Several policies if not maintained or updated at all, will have their implementation obsolete and becomes as never been implemented before at certain point of time. In your city, what do you think the P1S1 average full depletion time in years will be if not maintained at all?
☐ 1 year ☐ 3 years ☐ 5 years ☐ 10 years
Policy: (P1S2) List and prioritize critical services and assets
In general, implementing policies imposes costs on cities, what do you think the average spending of your city will be to fully implement the P1S2 policy?
☐ 10,000 Euros ☐ 50,000 Euros ☐ 100,000 Euros ☐ 500,000 Euros ☐ 1,000,000 Euros
Policies require time to be implemented, what do you think the average P1S2 full implementation required time in years will be in your city?
☐ 1 year ☐ 3 years ☐ 5 years ☐ 10 years
Several policies if not maintained or updated at all, will have their implementation obsolete and becomes as never been implemented before at certain point of time. In your city, what do you think the P1S2 average full depletion time in years will be if not maintained at all?
☐ 1 year ☐ 3 years ☐ 5 years ☐ 10 years
Policy: (P1M1) Analyse the interdependences when assessing and managing risks
In general, implementing policies imposes costs on cities, what do you think the average spending of your city will be to fully implement the P1M1 policy?

☐ 10,000 Euros	☐ 50,000 Euros	☐ 100,000 Euros	☐ 500,000 Euros	☐ 1,000,000 Euros

Policies require time to be implemented, what do you think the average P1M1 full implementation required time in years will be in your city?

☐ 1 year	☐ 3 years	☐ 5 years	☐ 10 years

Several policies if not maintained or updated at all, will have their implementation obsolete and becomes as never been implemented before at certain point of time. In your city, what do you think the P1M1 average full depletion time in years will be if not maintained at all?

☐ 1 year	☐ 3 years	☐ 5 years	☐ 10 years

Policy: (P1A1) Assess scenarios of shocks and their cascading effects

In general, implementing policies imposes costs on cities, what do you think the average spending of your city will be to fully implement the P1A1 policy?

☐ 10,000 Euros	☐ 50,000 Euros	☐ 100,000 Euros	☐ 500,000 Euros	☐ 1,000,000 Euros

Policies require time to be implemented, what do you think the average P1A1 full implementation required time in years will be in your city?

☐ 1 year	☐ 3 years	☐ 5 years	☐ 10 years

Several policies if not maintained or updated at all, will have their implementation obsolete and becomes as never been implemented before at certain point of time. In your city, what do you think the P1A1 average full depletion time in years will be if not maintained at all?

☐ 1 year	☐ 3 years	☐ 5 years	☐ 10 years

Policy: (P1R1) Undertake regular, and long-term, risk assessments using Risk Systemicity tools

In general, implementing policies imposes costs on cities, what do you think the average spending of your city will be to fully implement the P1R1 policy?

☐ 10,000 Euros	☐ 50,000 Euros	☐ 100,000 Euros	☐ 500,000 Euros	☐ 1,000,000 Euros

Policies require time to be implemented, what do you think the average P1R1 full implementation required time in years will be in your city?

☐ 1 year	☐ 3 years	☐ 5 years	☐ 10 years

Several policies if not maintained or updated at all, will have their implementation obsolete and becomes as never been implemented before at certain point of time. In your city, what do you think the P1R1 average full depletion time in years will be if not maintained at all?
☐ 1 year ☐ 3 years ☐ 5 years ☐ 10 years
(P2) Education and Training
Policy: (P2S1) Conduct training and arrange emergency drills with the emergency teams and Critical Infrastructures providers
In general, implementing policies imposes costs on cities, what do you think the average spending of your city will be to fully implement the P2S1 policy?
☐ 10,000 Euros ☐ 50,000 Euros ☐ 100,000 Euros ☐ 500,000 Euros ☐ 1,000,000 Euros
Policies require time to be implemented, what do you think the average P2S1 full implementation required time in years will be in your city?
☐ 1 year ☐ 3 years ☐ 5 years ☐ 10 years
Several policies if not maintained or updated at all, will have their implementation obsolete and becomes as never been implemented before at certain point of time. In your city, what do you think the P2S1 average full depletion time in years will be if not maintained at all?
☐ 1 year ☐ 3 years ☐ 5 years ☐ 10 years
Policy: (P2M1) Conduct training and arrange emergency drills including volunteers
In general, implementing policies imposes costs on cities, what do you think the average spending of your city will be to fully implement the P2M1 policy?
☐ 10,000 Euros ☐ 50,000 Euros ☐ 100,000 Euros ☐ 500,000 Euros ☐ 1,000,000 Euros
Policies require time to be implemented, what do you think the average P2M1 full implementation required time in years will be in your city?
☐ 1 year ☐ 3 years ☐ 5 years ☐ 10 years
Several policies if not maintained or updated at all, will have their implementation obsolete and becomes as never been implemented before at certain point of time. In your city, what do you think the P2M1 average full depletion time in years will be if not maintained at all?

☐ 1 year ☐ 3 years ☐ 5 years ☐ 10 years
Policy: (P2A3) Develop education programs in schools about the resilience action plan
In general, implementing policies imposes costs on cities, what do you think the average spending of your city will be to fully implement the P2A3 policy?
☐ 10,000 Euros ☐ 50,000 Euros ☐ 100,000 Euros ☐ 500,000 Euros ☐ 1,000,000 Euros
Policies require time to be implemented, what do you think the average P2A3 full implementation required time in years will be in your city?
☐ 1 year ☐ 3 years ☐ 5 years ☐ 10 years
Several policies if not maintained or updated at all, will have their implementation obsolete and becomes as never been implemented before at certain point of time. In your city, what do you think the P2A3 average full depletion time in years will be if not maintained at all?
☐ 1 year ☐ 3 years ☐ 5 years ☐ 10 years
Policy: (P2R2) Conduct frequent joint training exercises between European cities
In general, implementing policies imposes costs on cities, what do you think the average spending of your city will be to fully implement the P2R2 policy?
☐ 10,000 Euros ☐ 50,000 Euros ☐ 100,000 Euros ☐ 500,000 Euros ☐ 1,000,000 Euros
Policies require time to be implemented, what do you think the average P2R2 full implementation required time in years will be in your city?
☐ 1 year ☐ 3 years ☐ 5 years ☐ 10 years
Several policies if not maintained or updated at all, will have their implementation obsolete and becomes as never been implemented before at certain point of time. In your city, what do you think the P2R2 average full depletion time in years will be if not maintained at all?
☐ 1 year ☐ 3 years ☐ 5 years ☐ 10 years
Policy: (P2T1) Develop training plans in cooperation with other CITIES.

In general, implementing policies imposes costs on cities, what do you think the average spending of your city will be to fully implement the P2T1 policy?
☐ 10,000 Euros ☐ 50,000 Euros ☐ 100,000 Euros ☐ 500,000 Euros ☐ 1,000,000 Euros
Policies require time to be implemented, what do you think the average P2T1 full implementation required time in years will be in your city?
☐ 1 year ☐ 3 years ☐ 5 years ☐ 10 years
Several policies if not maintained or updated at all, will have their implementation obsolete and becomes as never been implemented before at certain point of time. In your city, what do you think the P2T1 average full depletion time in years will be if not maintained at all?
☐ 1 year ☐ 3 years ☐ 5 years ☐ 10 years
INFRASTRUCTURE AND RESOURCES
(I1) Reliability of CIs and their interdependences
Policy: (I1S1) Develop cooperation/collaboration agreements with critical providers
In general, implementing policies imposes costs on cities, what do you think the average spending of your city will be to fully implement the I1S1 policy?
☐ 10,000 Euros ☐ 50,000 Euros ☐ 100,000 Euros ☐ 500,000 Euros ☐ 1,000,000 Euros
Policies require time to be implemented, what do you think the average I1S1 full implementation required time in years will be in your city?
☐ 1 year ☐ 3 years ☐ 5 years ☐ 10 years
Several policies if not maintained or updated at all, will have their implementation obsolete and becomes as never been implemented before at certain point of time. In your city, what do you think the I1S1 average full depletion time in years will be if not maintained at all?
☐ 1 year ☐ 3 years ☐ 5 years ☐ 10 years
Policy: (I1S3) Develop contingency plans for critical infrastructures
In general, implementing policies imposes costs on cities, what do you think the average spending of your city will be to fully implement the I1S3 policy?
☐ 10,000 Euros ☐ 50,000 Euros ☐ 100,000 Euros ☐ 500,000 Euros ☐ 1,000,000 Euros

Policies require time to be implemented, what do you think the average I1S3 full implementation required time in years will be in your city?
☐ 1 year ☐ 3 years ☐ 5 years ☐ 10 years
Several policies if not maintained or updated at all, will have their implementation obsolete and becomes as never been implemented before at certain point of time. In your city, what do you think the I1S3 average full depletion time in years will be if not maintained at all?
☐ 1 year ☐ 3 years ☐ 5 years ☐ 10 years
Policy: (I1M1) Identify interdependencies of critical services at local level
In general, implementing policies imposes costs on cities, what do you think the average spending of your city will be to fully implement the I1M1 policy?
☐ 10,000 Euros ☐ 50,000 Euros ☐ 100,000 Euros ☐ 500,000 Euros ☐ 1,000,000 Euros
Policies require time to be implemented, what do you think the average I1M1 full implementation required time in years will be in your city?
☐ 1 year ☐ 3 years ☐ 5 years ☐ 10 years
Several policies if not maintained or updated at all, will have their implementation obsolete and becomes as never been implemented before at certain point of time. In your city, what do you think the I1M1 average full depletion time in years will be if not maintained at all?
☐ 1 year ☐ 3 years ☐ 5 years ☐ 10 years
Policy: (I1M3) Develop measures and monitoring systems to increase critical infrastructure redundancy and reliability
In general, implementing policies imposes costs on cities, what do you think the average spending of your city will be to fully implement the I1M3 policy?
☐ 10,000 Euros ☐ 50,000 Euros ☐ 100,000 Euros ☐ 500,000 Euros ☐ 1,000,000 Euros
Policies require time to be implemented, what do you think the average I1M3 full implementation required time in years will be in your city?
☐ 1 year ☐ 3 years ☐ 5 years ☐ 10 years

Several policies if not maintained or updated at all, will have their implementation obsolete and becomes as never been implemented before at certain point of time. In your city, what do you think the I1M3 average full depletion time in years will be if not maintained at all?
☐ 1 year ☐ 3 years ☐ 5 years ☐ 10 years
Policy: (I1M5) Carry out audits for critical infrastructure providers
In general, implementing policies imposes costs on cities, what do you think the average spending of your city will be to fully implement the I1M5 policy?
☐ 10,000 Euros ☐ 50,000 Euros ☐ 100,000 Euros ☐ 500,000 Euros ☐ 1,000,000 Euros
Policies require time to be implemented, what do you think the average I1M5 full implementation required time in years will be in your city?
☐ 1 year ☐ 3 years ☐ 5 years ☐ 10 years
Several policies if not maintained or updated at all, will have their implementation obsolete and becomes as never been implemented before at certain point of time. In your city, what do you think the I1M5 average full depletion time in years will be if not maintained at all?
☐ 1 year ☐ 3 years ☐ 5 years ☐ 10 years
Policy: (I1T1) Encourage the continuous improvement of policies, to take advantage of any shock and stress to bounce forward and improve or re-design.
In general, implementing policies imposes costs on cities, what do you think the average spending of your city will be to fully implement the I1T1 policy?
☐ 10,000 Euros ☐ 50,000 Euros ☐ 100,000 Euros ☐ 500,000 Euros ☐ 1,000,000 Euros
Policies require time to be implemented, what do you think the average I1T1 full implementation required time in years will be in your city?
☐ 1 year ☐ 3 years ☐ 5 years ☐ 10 years
Several policies if not maintained or updated at all, will have their implementation obsolete and becomes as never been implemented before at certain point of time. In your city, what do you think the I1T1 average full depletion time in years will be if not maintained at all?

☐ 1 year ☐ 3 years ☐ 5 years ☐ 10 years
(I2) Resources to build up resilience and to response
Policy: (I2S2) Develop a list of the currently available response physical resources
In general, implementing policies imposes costs on cities, what do you think the average spending of your city will be to fully implement the I2S2 policy?
☐ 10,000 Euros ☐ 50,000 Euros ☐ 100,000 Euros ☐ 500,000 Euros ☐ 1,000,000 Euros
Policies require time to be implemented, what do you think the average I2S2 full implementation required time in years will be in your city?
☐ 1 year ☐ 3 years ☐ 5 years ☐ 10 years
Several policies if not maintained or updated at all, will have their implementation obsolete and becomes as never been implemented before at certain point of time. In your city, what do you think the I2S2 average full depletion time in years will be if not maintained at all?
☐ 1 year ☐ 3 years ☐ 5 years ☐ 10 years
Policy: (I2M1) Allow for the resilience action plan in the local government budget.
In general, implementing policies imposes costs on cities, what do you think the average spending of your city will be to fully implement the I2M1 policy?
☐ 10,000 Euros ☐ 50,000 Euros ☐ 100,000 Euros ☐ 500,000 Euros ☐ 1,000,000 Euros
Policies require time to be implemented, what do you think the average I2M1 full implementation required time in years will be in your city?
☐ 1 year ☐ 3 years ☐ 5 years ☐ 10 years
Several policies if not maintained or updated at all, will have their implementation obsolete and becomes as never been implemented before at certain point of time. In your city, what do you think the I2M1 average full depletion time in years will be if not maintained at all?
☐ 1 year ☐ 3 years ☐ 5 years ☐ 10 years
Policy: (I2M2) Promote resources /tool sharing among CI providers within a region during crises

In general, implementing policies imposes costs on cities, what do you think the average spending of your city will be to fully implement the I2M2 policy?
☐ 10,000 Euros ☐ 50,000 Euros ☐ 100,000 Euros ☐ 500,000 Euros ☐ 1,000,000 Euros
Policies require time to be implemented, what do you think the average I2M2 full implementation required time in years will be in your city?
☐ 1 year ☐ 3 years ☐ 5 years ☐ 10 years
Several policies if not maintained or updated at all, will have their implementation obsolete and becomes as never been implemented before at certain point of time. In your city, what do you think the I2M2 average full depletion time in years will be if not maintained at all?
☐ 1 year ☐ 3 years ☐ 5 years ☐ 10 years
Policy: (I2A1) Promote and provide incentives for the initiatives that contribute to build resilience
In general, implementing policies imposes costs on cities, what do you think the average spending of your city will be to fully implement the I2A1 policy?
☐ 10,000 Euros ☐ 50,000 Euros ☐ 100,000 Euros ☐ 500,000 Euros ☐ 1,000,000 Euros
Policies require time to be implemented, what do you think the average I2A1 full implementation required time in years will be in your city?
☐ 1 year ☐ 3 years ☐ 5 years ☐ 10 years
Several policies if not maintained or updated at all, will have their implementation obsolete and becomes as never been implemented before at certain point of time. In your city, what do you think the I2A1 average full depletion time in years will be if not maintained at all?
☐ 1 year ☐ 3 years ☐ 5 years ☐ 10 years
Policy: (I2A4) Promote and provide incentives for the development of sustainable urban infrastructures
In general, implementing policies imposes costs on cities, what do you think the average spending of your city will be to fully implement the I2A4 policy?
☐ 10,000 Euros ☐ 50,000 Euros ☐ 100,000 Euros ☐ 500,000 Euros ☐ 1,000,000 Euros

Policies require time to be implemented, what do you think the average I2A4 full implementation required time in years will be in your city?
☐ 1 year ☐ 3 years ☐ 5 years ☐ 10 years
Several policies if not maintained or updated at all, will have their implementation obsolete and becomes as never been implemented before at certain point of time. In your city, what do you think the I2A4 average full depletion time in years will be if not maintained at all?
☐ 1 year ☐ 3 years ☐ 5 years ☐ 10 years
Policy: (I2R1) Promote and provide incentives to stakeholders for investment in R&D&I projects regarding Resilience
In general, implementing policies imposes costs on cities, what do you think the average spending of your city will be to fully implement the I2R1 policy?
☐ 10,000 Euros ☐ 50,000 Euros ☐ 100,000 Euros ☐ 500,000 Euros ☐ 1,000,000 Euros
Policies require time to be implemented, what do you think the average I2R1 full implementation required time in years will be in your city?
☐ 1 year ☐ 3 years ☐ 5 years ☐ 10 years
Several policies if not maintained or updated at all, will have their implementation obsolete and becomes as never been implemented before at certain point of time. In your city, what do you think the I2R1 average full depletion time in years will be if not maintained at all?
☐ 1 year ☐ 3 years ☐ 5 years ☐ 10 years
Policy: (I2T2) Monitor the insurance level of stakeholders
In general, implementing policies imposes costs on cities, what do you think the average spending of your city will be to fully implement the I2T2 policy?
☐ 10,000 Euros ☐ 50,000 Euros ☐ 100,000 Euros ☐ 500,000 Euros ☐ 1,000,000 Euros
Policies require time to be implemented, what do you think the average I2T2 full implementation required time in years will be in your city?
☐ 1 year ☐ 3 years ☐ 5 years ☐ 10 years

Several policies if not maintained or updated at all, will have their implementation obsolete and becomes as never been implemented before at certain point of time. In your city, what do you think the I2T2 average full depletion time in years will be if not maintained at all?
☐ 1 year ☐ 3 years ☐ 5 years ☐ 10 years
COOPERATION
(C1) Development of partnerships with city stakeholders
Policy: (C1S2) Develop a public website with emergency information
In general, implementing policies imposes costs on cities, what do you think the average spending of your city will be to fully implement the C1S2 policy?
☐ 10,000 Euros ☐ 50,000 Euros ☐ 100,000 Euros ☐ 500,000 Euros ☐ 1,000,000 Euros
Policies require time to be implemented, what do you think the average C1S2 full implementation required time in years will be in your city?
☐ 1 year ☐ 3 years ☐ 5 years ☐ 10 years
Several policies if not maintained or updated at all, will have their implementation obsolete and becomes as never been implemented before at certain point of time. In your city, what do you think the C1S2 average full depletion time in years will be if not maintained at all?
☐ 1 year ☐ 3 years ☐ 5 years ☐ 10 years
Policy: (C1M1) Develop a stakeholder engagement plan defining its roles and responsibilities
In general, implementing policies imposes costs on cities, what do you think the average spending of your city will be to fully implement the C1M1 policy?
☐ 10,000 Euros ☐ 50,000 Euros ☐ 100,000 Euros ☐ 500,000 Euros ☐ 1,000,000 Euros
Policies require time to be implemented, what do you think the average C1M1 full implementation required time in years will be in your city?
☐ 1 year ☐ 3 years ☐ 5 years ☐ 10 years
Several policies if not maintained or updated at all, will have their implementation obsolete and becomes as never been implemented before at certain point of time. In your city, what do you think the C1M1 average full depletion time in years will be if not maintained at all?
☐ 1 year ☐ 3 years ☐ 5 years ☐ 10 years

Policy: (C1A1) Align the objectives of different stakeholders and develop a common understanding of resilience
In general, implementing policies imposes costs on cities, what do you think the average spending of your city will be to fully implement the C1A1 policy?
☐ 10,000 Euros ☐ 50,000 Euros ☐ 100,000 Euros ☐ 500,000 Euros ☐ 1,000,000 Euros
Policies require time to be implemented, what do you think the average C1A1 full implementation required time in years will be in your city?
☐ 1 year ☐ 3 years ☐ 5 years ☐ 10 years
Several policies if not maintained or updated at all, will have their implementation obsolete and becomes as never been implemented before at certain point of time. In your city, what do you think the C1A1 average full depletion time in years will be if not maintained at all?
☐ 1 year ☐ 3 years ☐ 5 years ☐ 10 years
Policy: (C1A4) Develop a public communication platform to interact with stakeholders
In general, implementing policies imposes costs on cities, what do you think the average spending of your city will be to fully implement the C1A4 policy?
☐ 10,000 Euros ☐ 50,000 Euros ☐ 100,000 Euros ☐ 500,000 Euros ☐ 1,000,000 Euros
Policies require time to be implemented, what do you think the average C1A4 full implementation required time in years will be in your city?
☐ 1 year ☐ 3 years ☐ 5 years ☐ 10 years
Several policies if not maintained or updated at all, will have their implementation obsolete and becomes as never been implemented before at certain point of time. In your city, what do you think the C1A4 average full depletion time in years will be if not maintained at all?
☐ 1 year ☐ 3 years ☐ 5 years ☐ 10 years
Policy: (C1R3) Develop a public platform to enhance learning among city stakeholders
In general, implementing policies imposes costs on cities, what do you think the average spending of your city will be to fully implement the C1R3 policy?

☐ 10,000 Euros	☐ 50,000 Euros	☐ 100,000 Euros	☐ 500,000 Euros	☐ 1,000,000 Euros

Policies require time to be implemented, what do you think the average C1R3 full implementation required time in years will be in your city?

☐ 1 year	☐ 3 years	☐ 5 years	☐ 10 years

Several policies if not maintained or updated at all, will have their implementation obsolete and becomes as never been implemented before at certain point of time. In your city, what do you think the C1R3 average full depletion time in years will be if not maintained at all?

☐ 1 year	☐ 3 years	☐ 5 years	☐ 10 years

Policy: (C1T2) Involve all stakeholders in the learning process

In general, implementing policies imposes costs on cities, what do you think the average spending of your city will be to fully implement the C1T2 policy?

☐ 10,000 Euros	☐ 50,000 Euros	☐ 100,000 Euros	☐ 500,000 Euros	☐ 1,000,000 Euros

Policies require time to be implemented, what do you think the average C1T2 full implementation required time in years will be in your city?

☐ 1 year	☐ 3 years	☐ 5 years	☐ 10 years

Several policies if not maintained or updated at all, will have their implementation obsolete and becomes as never been implemented before at certain point of time. In your city, what do you think the C1T2 average full depletion time in years will be if not maintained at all?

☐ 1 year	☐ 3 years	☐ 5 years	☐ 10 years

(C2) Involvement in resilience networks of cities

Policy: (C2M1) Establish alliances with cities facing similar risks

In general, implementing policies imposes costs on cities, what do you think the average spending of your city will be to fully implement the C2M1 policy?

☐ 10,000 Euros	☐ 50,000 Euros	☐ 100,000 Euros	☐ 500,000 Euros	☐ 1,000,000 Euros

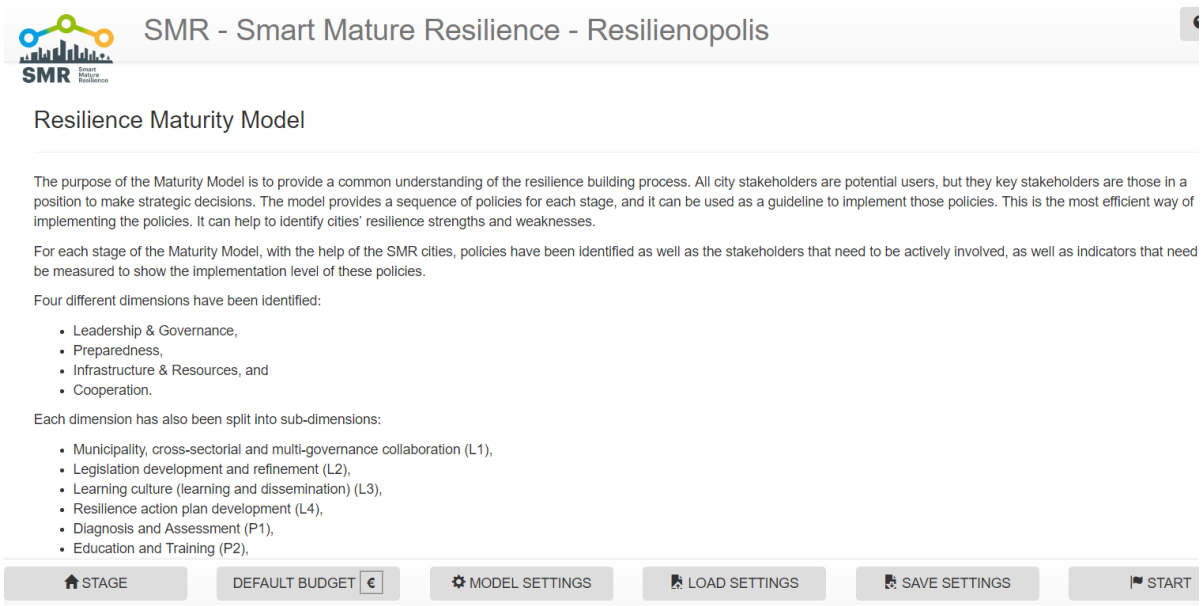
Policies require time to be implemented, what do you think the average C2M1 full implementation required time in years will be in your city?

☐ 1 year ☐ 3 years ☐ 5 years ☐ 10 years
Several policies if not maintained or updated at all, will have their implementation obsolete and becomes as never been implemented before at certain point of time. In your city, what do you think the C2M1 average full depletion time in years will be if not maintained at all?
☐ 1 year ☐ 3 years ☐ 5 years ☐ 10 years
Policy: (C2A2) Develop formal partnerships with regional stakeholders
In general, implementing policies imposes costs on cities, what do you think the average spending of your city will be to fully implement the C2A2 policy?
☐ 10,000 Euros ☐ 50,000 Euros ☐ 100,000 Euros ☐ 500,000 Euros ☐ 1,000,000 Euros
Policies require time to be implemented, what do you think the average C2A2 full implementation required time in years will be in your city?
☐ 1 year ☐ 3 years ☐ 5 years ☐ 10 years
Several policies if not maintained or updated at all, will have their implementation obsolete and becomes as never been implemented before at certain point of time. In your city, what do you think the C2A2 average full depletion time in years will be if not maintained at all?
☐ 1 year ☐ 3 years ☐ 5 years ☐ 10 years
Policy: (C2R1) Participate proactively in regional, national and international networks to promote initiatives, exchange experiences and learn
In general, implementing policies imposes costs on cities, what do you think the average spending of your city will be to fully implement the C2R1 policy?
☐ 10,000 Euros ☐ 50,000 Euros ☐ 100,000 Euros ☐ 500,000 Euros ☐ 1,000,000 Euros
Policies require time to be implemented, what do you think the average C2R1 full implementation required time in years will be in your city?
☐ 1 year ☐ 3 years ☐ 5 years ☐ 10 years
Several policies if not maintained or updated at all, will have their implementation obsolete and becomes as never been implemented before at certain point of time. In your city, what do you think the C2R1 average full depletion time in years will be if not maintained at all?

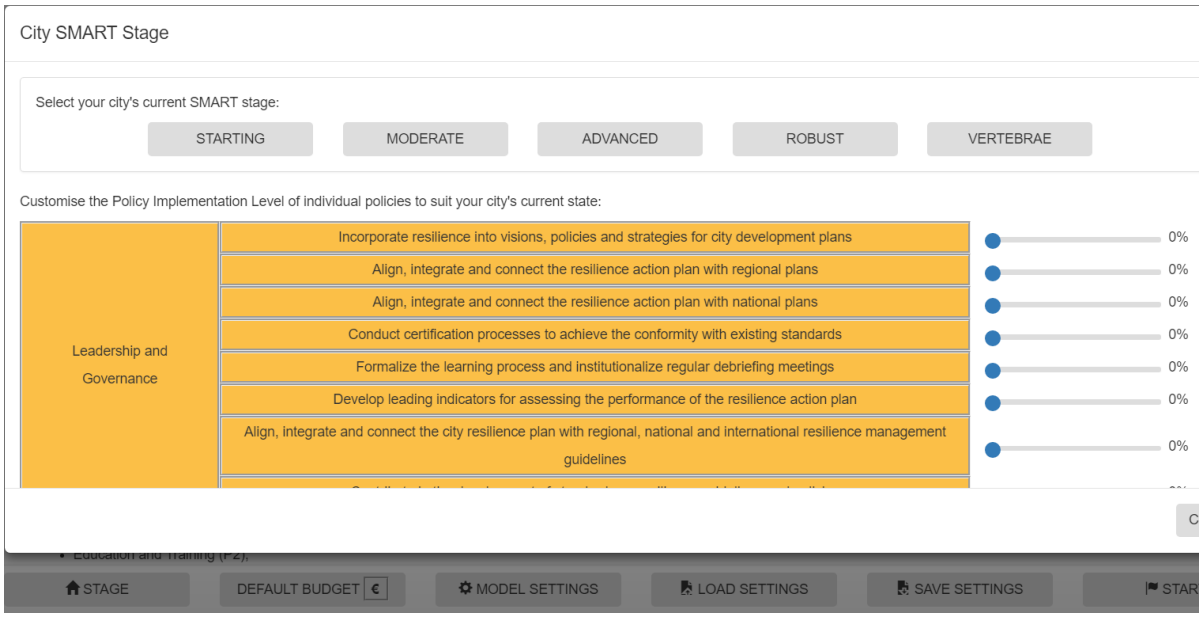
☐ 1 year ☐ 3 years ☐ 5 years ☐ 10 years
Policy: (C2T1) Active involvement of local authority and stakeholders in networks (local, national, European & Global)
In general, implementing policies imposes costs on cities, what do you think the average spending of your city will be to fully implement the C2T1 policy?
☐ 10,000 Euros ☐ 50,000 Euros ☐ 100,000 Euros ☐ 500,000 Euros ☐ 1,000,000 Euros
Policies require time to be implemented, what do you think the average C2T1 full implementation required time in years will be in your city?
☐ 1 year ☐ 3 years ☐ 5 years ☐ 10 years
Several policies if not maintained or updated at all, will have their implementation obsolete and becomes as never been implemented before at certain point of time. In your city, what do you think the C2T1 average full depletion time in years will be if not maintained at all?
☐ 1 year ☐ 3 years ☐ 5 years ☐ 10 years

ANNEX 7: GUIDANCE FOR USING THE SMR SIMULATION TOOL

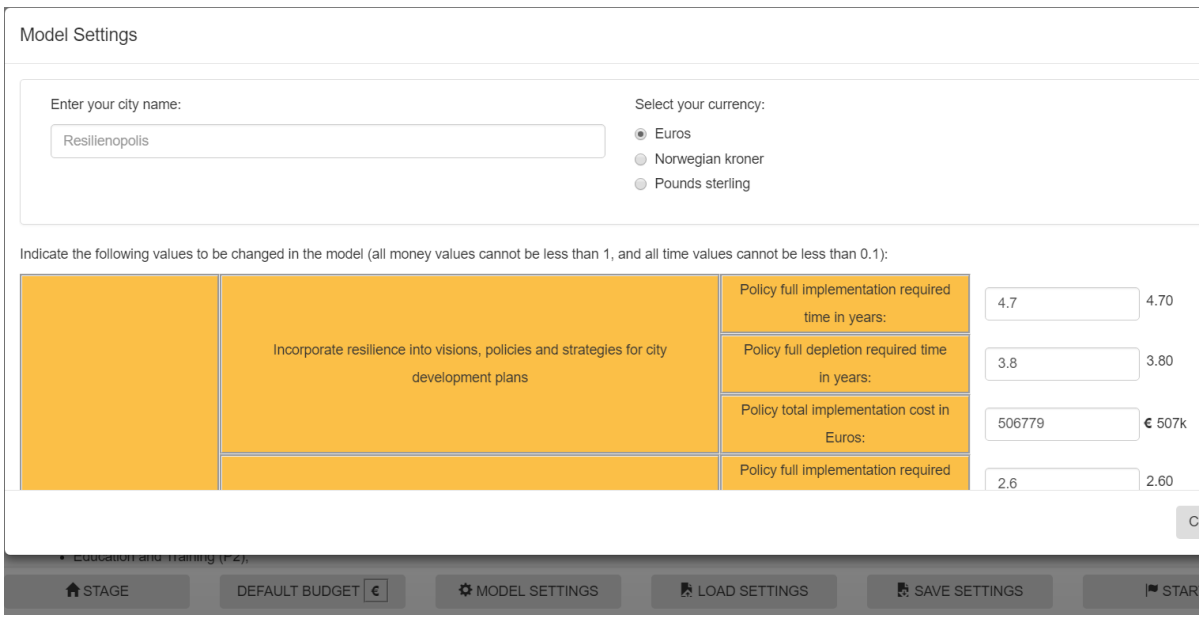
The initial page of the SMR simulation tool provides introductory information to the Resilience Maturity Model. This simulation tool is based on the general case of the city of *Resilienopolis*. Nonetheless, the initial page provides the functionalities that enable the user to tailor it to the case of her/his city if needed, by indicating the city's initial situation before starting the simulation game.



The user can indicate the city's current SMART stage by clicking "**STAGE**" **button** in the bottom of the initial page. Using the City SMART stage dialogue-box, she/he can click the button that suits the city's stage, or set individual policies initial implementation level via corresponding sliders.

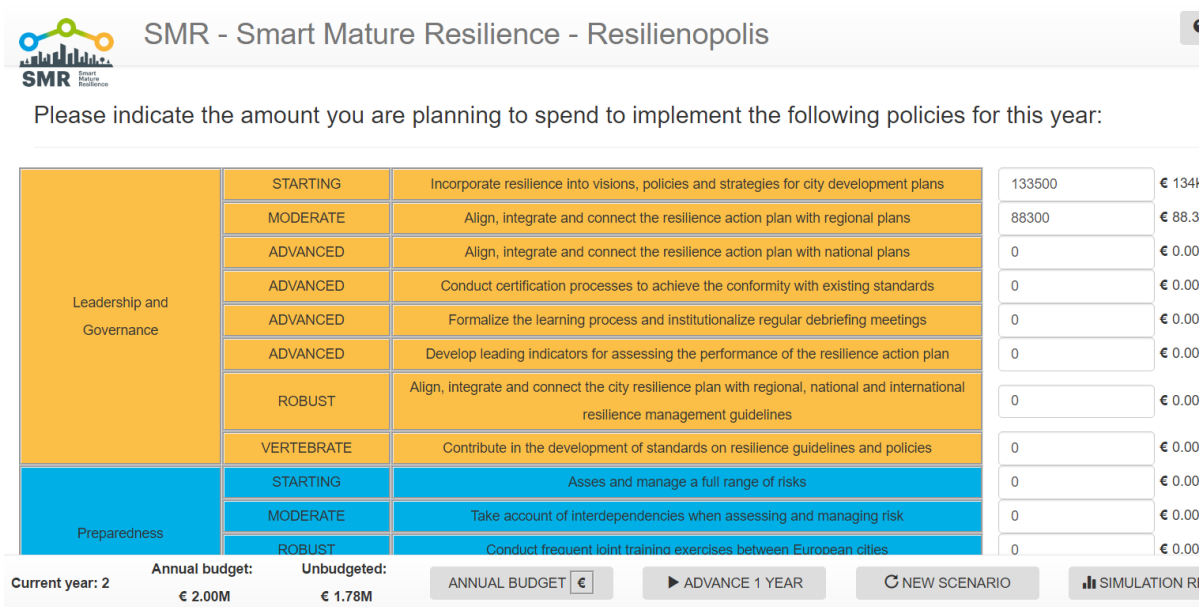


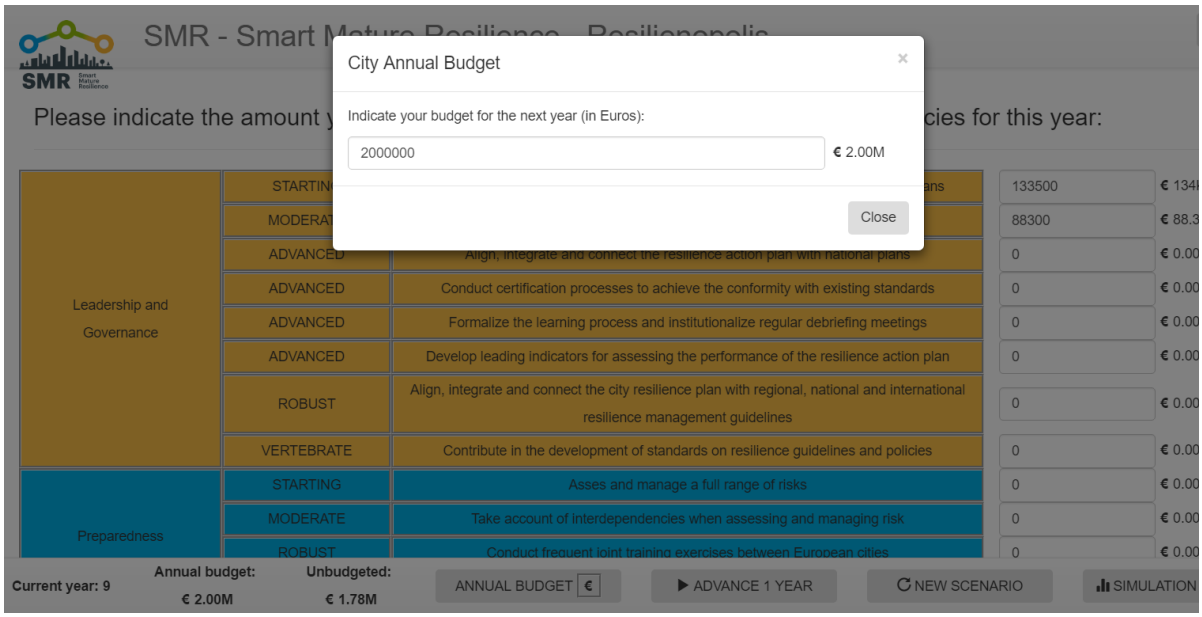
The user can also change the default annual budget by clicking "**ANNUAL BUDGET**" button. By clicking "**MODEL SETTINGS**" button, the user can further change the city name and currency, in addition to model's internal parameters (for example time and cost needed to implement certain policy).



All initial settings the user has made could be saved in a file for later usage by clicking "**SAVE SETTINGS**" **button**. Saved settings file could be loaded by clicking "**LOAD SETTINGS**" **button**. Finally, to finish the initialization the user can click "**START**" **button** and proceed to the simulation page to start the game.

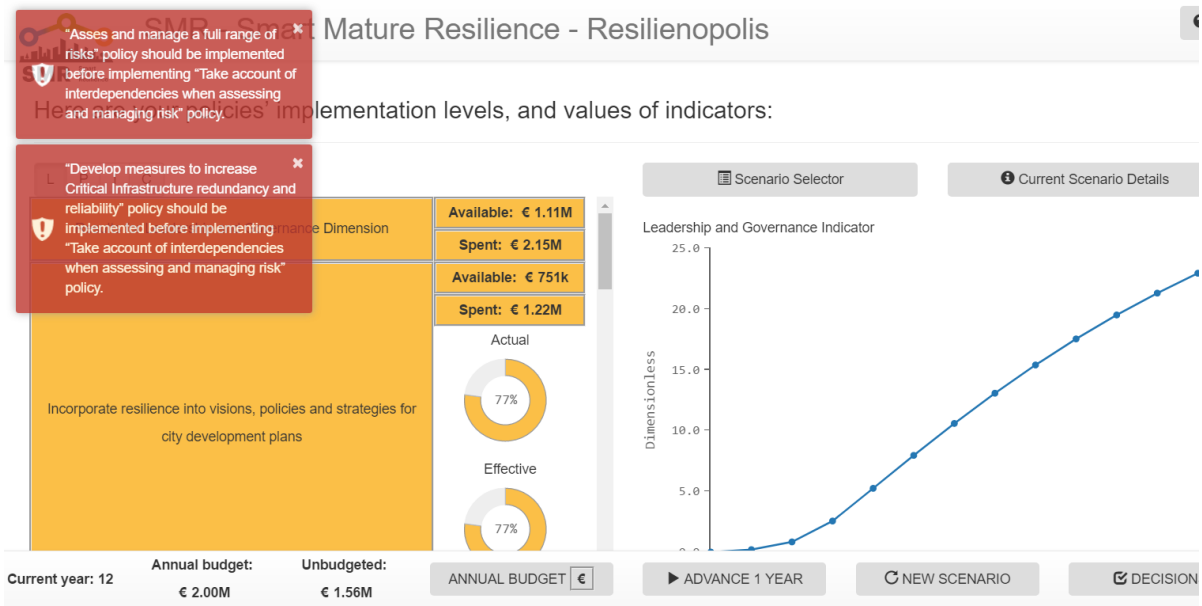
In the simulation page, the user can decide the devoted budget (for the current simulation year) for implementing the individual policies by entering the value in the corresponding textboxes. At the bottom left corner of the page, the user also can follow the current simulation time through the "**Current year**", in addition to the available and left budget (for the current simulation year) through the "**Available budget**" and "**Budget left**" respectively. To accommodate for any budget cuts or changes for the next simulation year, the user can change the next year's budget value by clicking the "**ANNUAL BUDGET**" **button**.



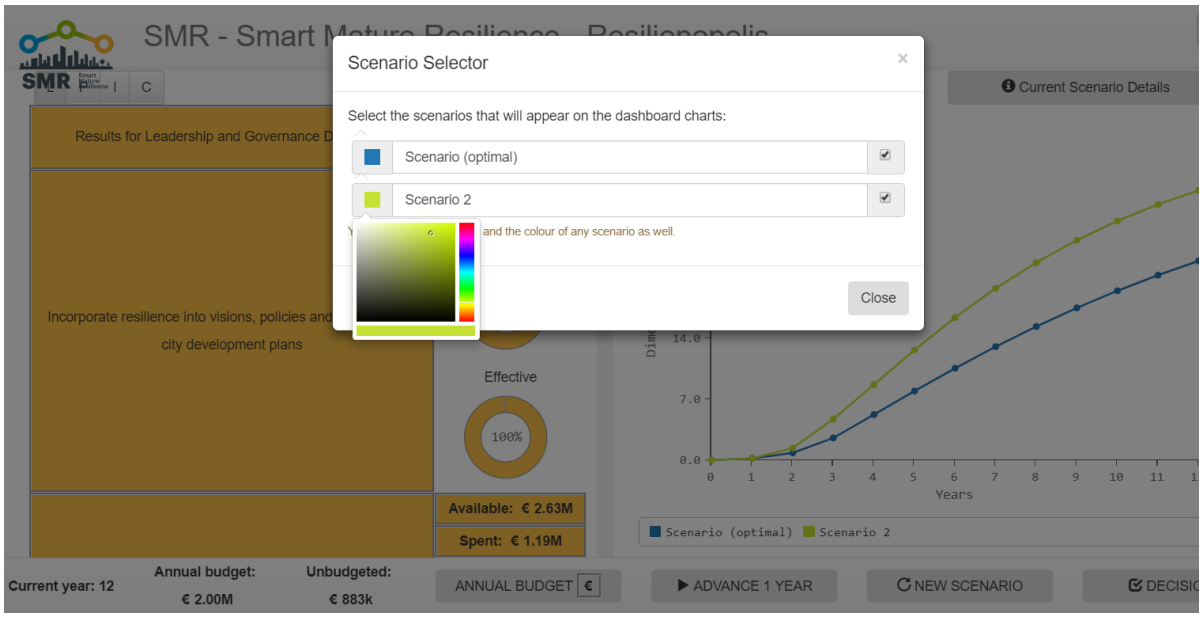


At the bottom of the page, the user can progress simulation one step further by pressing the "**ADVANCE 1 YEAR**" **button**. Pressing the "**NEW SCENARIO**" **button** stops the current simulation scenario, and starts a new one. The "**SIMULATION RESULTS**" **button** takes the user to the simulation results page. In the simulation results page, the user can see the individual policies' **current actual and effective implementation levels**, in addition to the **time-behaviour graphs** of SMR dimensions' indicators. On a time-behaviour graph, the user will be able to see maximum of three different scenarios from the scenarios she/he has simulated.

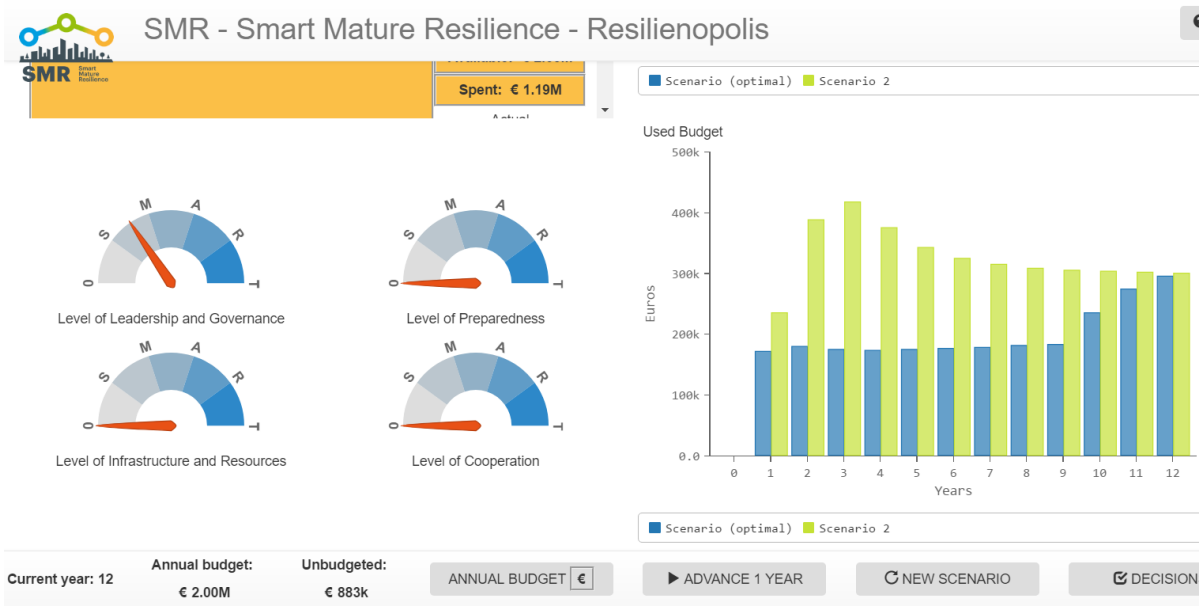
Every 4 years, the tool will provide help messages indicating any problems in the sequence of the user's spending decisions.



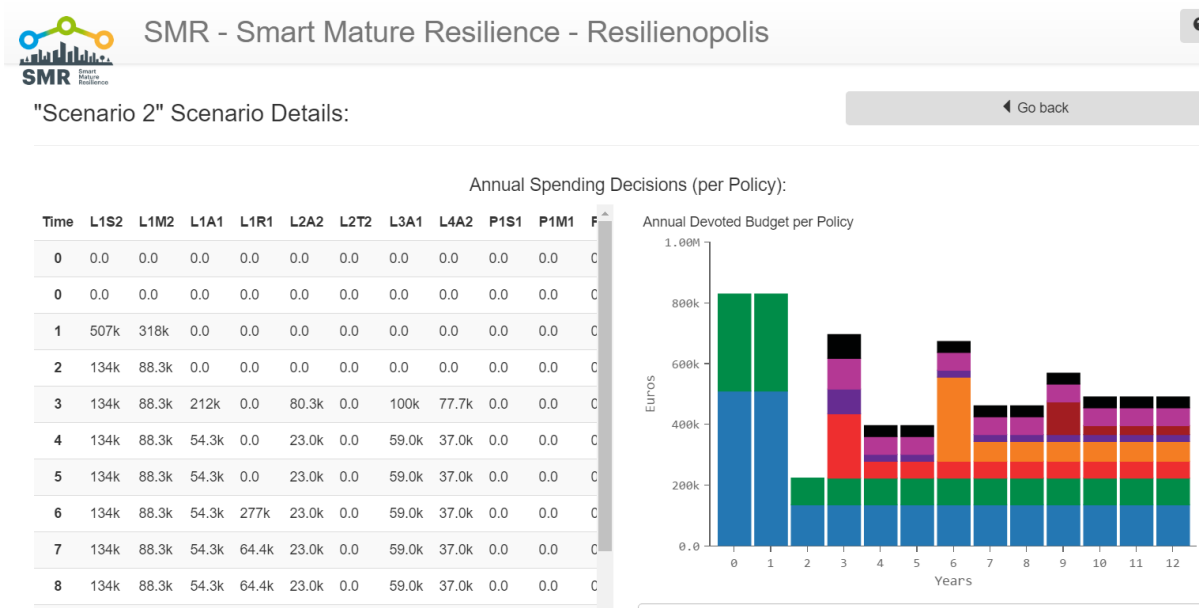
The user can press the "**Scenario Selector**" **button** that exits on the top of the time-behaviour graph to select which scenarios to show, name them, and select their colours, via "**Scenario Selector**" **dialogue-box**. Only the scenarios with their respective **checkbox** selected will be shown on the graphs. To change a scenario name, the user needs to overwrite it. To change its colour the user can press on the small coloured box and pick a new colour.



The **SMART power gauge meters** by the bottom of the results page show the user her/his city's SMART stage per individual dimension at the current simulation time. The user can also find out how much she/he has spent each year via the Used Budget **time-behaviour graph**.



At the bottom left corner of this page, the user can still see the current simulation time, available and left budget. At the bottom of this page as well, the user can progress simulation one step further by pressing the "**ADVANCE 1 YEAR**" **button**. The "**NEW SCENARIO**" **button** stops the current simulation scenario, and starts a new one. The "**DECISIONS**" **button** takes the user back the simulation decisions page. Detailed information about the user's current scenario including the user's decisions history can be called by clicking "**Current Scenario Details**" **button** available to the right of the "**Scenario Selector**" **button**.



Time	L1S2	L1M2	L1A1	L1R1	L2A2	L2T2	L3A1	L4A2	P1S1	P1M1
0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1	507k	318k	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	134k	88.3k	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3	134k	88.3k	212k	0.0	80.3k	0.0	100k	77.7k	0.0	0.0
4	134k	88.3k	54.3k	0.0	23.0k	0.0	59.0k	37.0k	0.0	0.0
5	134k	88.3k	54.3k	0.0	23.0k	0.0	59.0k	37.0k	0.0	0.0
6	134k	88.3k	54.3k	277k	23.0k	0.0	59.0k	37.0k	0.0	0.0
7	134k	88.3k	54.3k	64.4k	23.0k	0.0	59.0k	37.0k	0.0	0.0
8	134k	88.3k	54.3k	64.4k	23.0k	0.0	59.0k	37.0k	0.0	0.0

The "**Help**" **button** is available on the up-right corner of all pages. By clicking it, the user can view a quick user guide for the simulation tool.

ANNEX 8: QUESTIONNAIRE PILOT IMPLEMENTATION: THE SIMULATION TOOL TO IMPROVE THE RESILIENCE OF A CITY

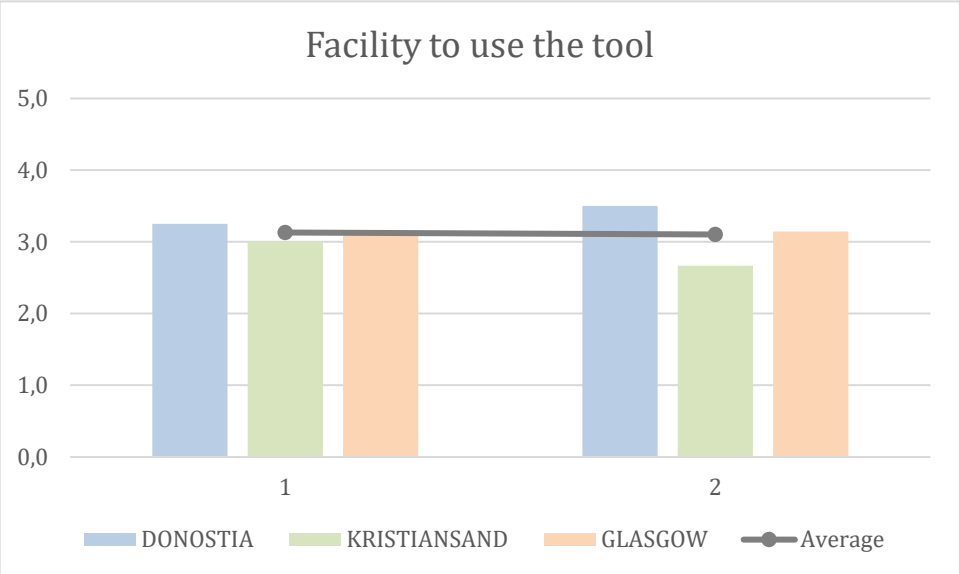
The following questionnaire was carried out in the three Tier1 cities of the project during the pilot implementations, namely: Donostia (blue), Kristiansand (green) and Glasgow (orange).

Following the asked 18 questions and answers are presented, as well as the comments related. The 18 questions were grouped depending the topic: facility to use the tool, the parameter estimation of the tool, policies implementation, relationships and temporal order of the policies and simulation results.

FACILITY TO USE THE TOOL

1. Do you think the tool is easy to use?

2. Do you think the tool enables to understand how the city resilience level can be improved?



COMMENTS

- The applied concepts are based on theoretical aspects and sometimes is hard to understand. Yet the tool is easy to use.
- It is necessary to previously understand the applied concepts. However, the tool is user friendly, the messages help a lot.
- The tool is not complex, the concepts yes.
- Putting a cost/price on the different STRATEGIES in our masterplan is difficult. We need to discuss concrete measures and find out how these measures relate to the area of resilience.
- Need a button for save
- The tool is fairly complicated. To understand its application. To put strategic work in practice.
- Potentially the tool has a lot to offer. However, it is hard to understand city context without demographic data on health/ attainment.
- Simplicity required as tool can become complicated.
- Difficult in determining what the budget would be – resilience is so far reaching- are you to assume that whole budget affects resilience in some way.

THE PARAMETER ESTIMATION OF THE TOOL

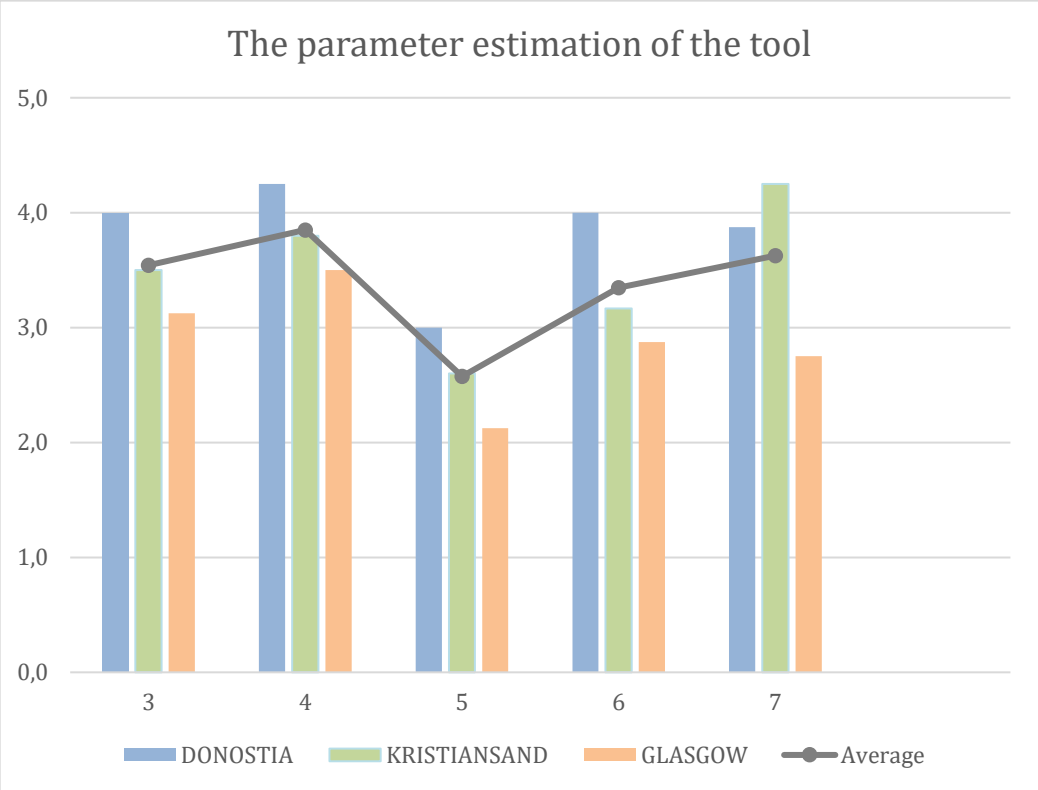
3. The parameter estimation has helped me to estimate the size of the resilience building process.

4. The group discussions when estimating the parameters have helped me to understand the complexity of the problem and get to know different points of view.

5. The tool is flexible enough to be particularized to my city.

6. The estimation has helped me to identify the policies that need more resources and be able to prioritizes them.

7. The estimation has helped me to identify the policies that need more time to be implemented.



- The parameter estimation is the most complex part of the tool. Guessing with the values is complicate.
- The tool needs to be well prepared with a previous discussion on where and how to use it.
- Basing tool on budget misses ability to compare with other similar experiences.
- Needs further thought/discussion needs shared amongst wider potential users.

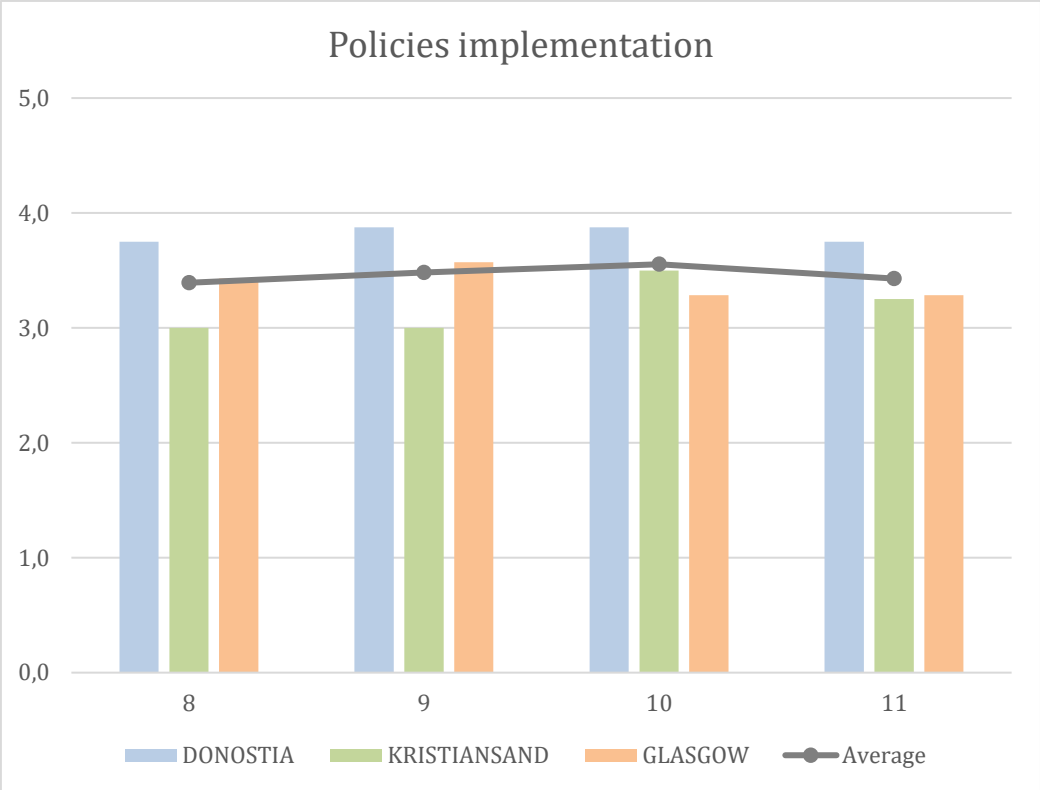
POLICIES IMPLEMENTATION

8. The policies' implementation has helped me to have a more holistic point of view of the problem

9. The policies' implementation helps me to take decisions concerning the distribution of resources.

10. The policies' implementation has helped me to understand that in order to maintain the policies' level, you must continue allocating resources.

11. The policies' implementation helped me to better understand the scope of each policy.



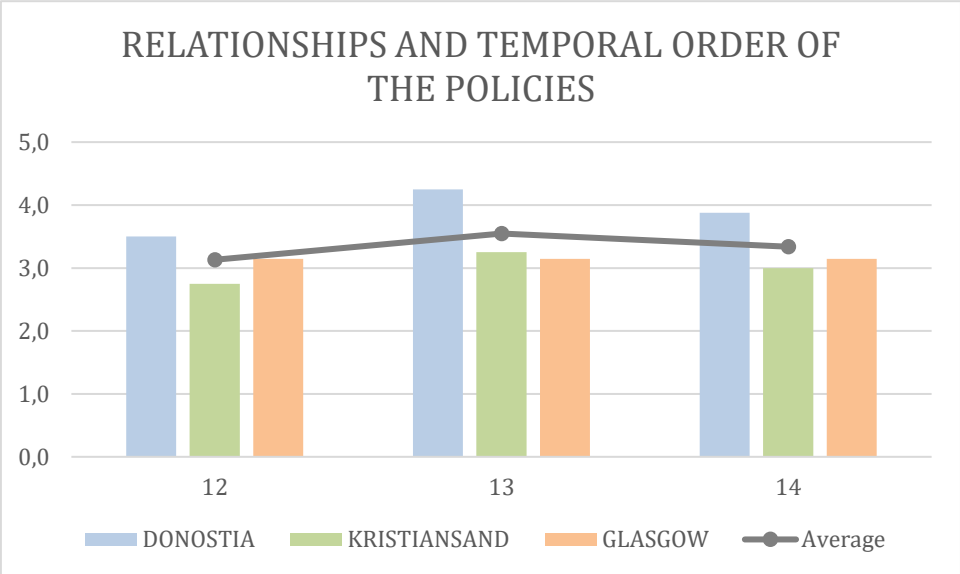
- The policy implementation does not take into account the complex tiers inside an organization.
- More time testing the tool.
- Need further "hands on" use of tool to enable usefulness decision
- Resources should not be only financial

RELATIONSHIPS AND TEMPORAL ORDER OF THE POLICIES

12. The tool helps me to identify which are the relationships existing between policies.

13. The tool helps me to identify the temporal order in which policies should be implemented to get the maximum resource efficiency.

14. The messages appearing during the simulation help me to identify the relationships between the policies and understand the temporal order in which they should be implemented.



- The tool facilitates to understand the temporal relationships yet to understand the interrelationships between policies I would rather need more time.
- Yes, it gave indication of the benefits of synchronizing policy correctly – however soft output (outcomes for people/communities) are missing

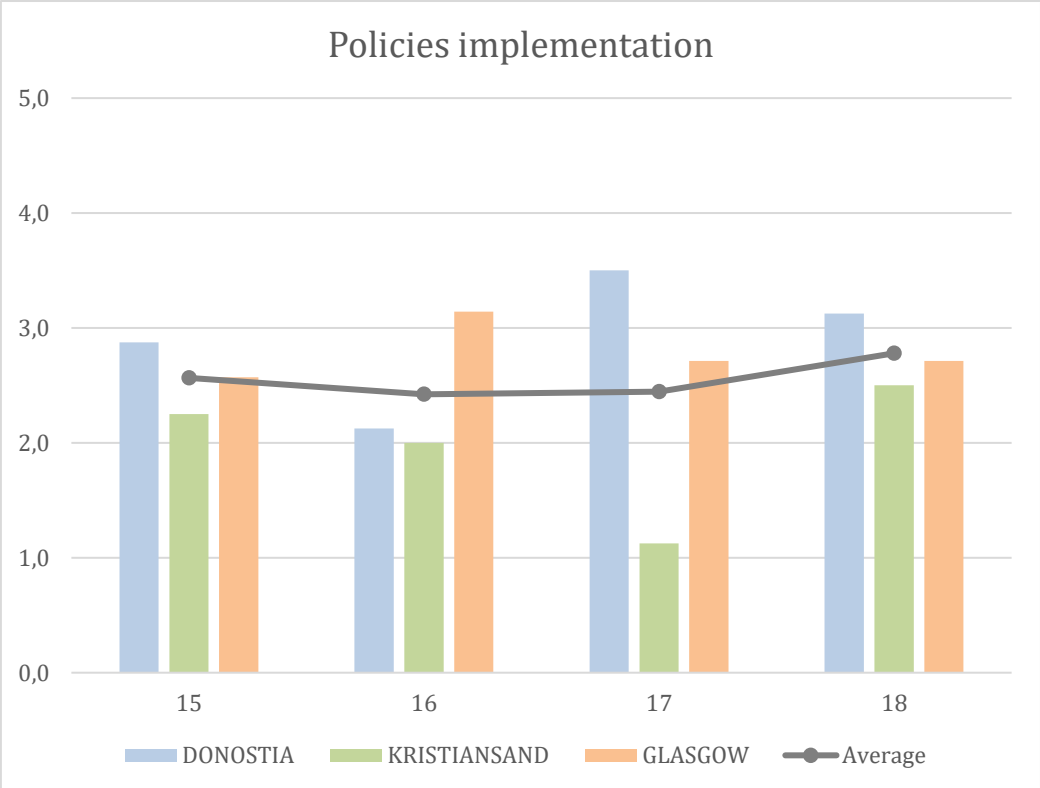
SIMULATION RESULTS

15. The results showed by the tool are close to reality.

16. Comparing the expected results with the ones given by the simulation has helped me to better understand how the city resilience building process works.

17. The results given by the tool are easily understood.

18. The results given by the tool are enough to understand the logic of the simulation.



- The group was not able to discuss the total complexity of the study case and therefore it was difficult to give a good simulation.
- We would need even better selected groups and more time to get a realistic output from the simulation.
- Making one or two working days for the urban planning unit together with stakeholders from relevant areas

POSITIVE ASPECTS

- The tool facilitates to understand the interrelationships and the temporal order of the policies.
- The tool makes you consider the lineal and transversal relationships that you might not take into account before.
- It is very important to create multidisciplinary groups in order to achieve resilience.
- The tool and the carried out session help to better understand the resilience building process.
- Achieving resilience is not a short term strategy.
- In order to success in the resilience building process someone needs to coordinate and guide the project.
- The tool helps to prioritize the efforts needed to build resilience.
- The tool helps to realize policies need to be not only implemented but also maintained. It looks obvious yet we sometimes forget it.
- I learnt that we do not have good enough, feedback sessions processes of urban planning.
- There are many other aspects that also become learning for the grow.
- I learnt that the tool is complex but very useful in the right context.
- The 4 dimensions is a great way to sort out policies to work on.
- Some useful issues to take into account when thinking about resilience.
- Some additional sense of policies interaction.
- The tool has great potential pulling out key areas of resilience
- Greater awareness of co-dependence and inter-relationships

SUGGESTED IMPROVEMENTS

- Languages: Basque and Spanish
- Instead of using “depletion” years indicate maintenance cost.
- Provide real examples of other cities in order to facilitate the process of parametrizing.
- It would be interesting to develop a tool based on this one but more particularized to the reality to each city.
- Simplicity the tool. To be more user friendly. Make it more simple to apply to process or delivery of projects.
- Use of population/depravation/health/educational data would add significant contextual value.
- Be clear in terms of what we are measuring. Is this performance that the measure should show but what if things happen that mean you have to shift focus?
- Forecasting/estimates can only be just what things are yet don’t necessarily capture all of the parts that are more difficult to measure and quantify.
- The buttons at the bottom should be moved up. Maybe change the color of the button to see where you are when operating in the program.
- Should be used by right people for the right reasons on the right policies.