Risk perception and knowledge in flood risk management: analytical modelling of citizens' attitudes to protective behavior in flood risk situation

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11

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Doctor of Philosophy in Environmental and Building Risk and Development

Coordinator: Prof. Michele Mossa

XXXIV CYCLE
Curriculum: ICAR 20 - Urban and regional planning;
ICAR 02- Hydraulic and marine constructions and hydrology;

DICATECh
Department of Civil, Environmental, Building Engineering and Chemistry

Stefania Santoro

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Final Dissertation

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Politecnico di Bari

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Al Magnifico Rettore
del Politecnico di Bari

La sottoscritta Stefania Santoro nata a Bari il 26/12/1987, residente a Bari in via Celentano 78, e-mail: stefania.santoro@poliba.it, iscritta al 3° anno di Corso di Dottorato di Ricerca in Rischio, sviluppo ambientale, territoriale ed edilizio, ciclo XXXIV,
ed essendo stato ammesso a sostenere l'esame finale con la prevista discussione della tesi dal titolo:

Percezione e conoscenza nella gestione del rischio alluvione: modelli di analisi della propensione dei cittadini al comportamento protettivo

DICHIARA

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Luogo e data Bari, 24/03/2022 Firma ____

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EXTENDED ABSTRACT (ENG)

The effects of flooding on the urban environment are considered among the leading causes of social crisis, as they could drastically affect the socioeconomic status of a community. An increase in events can significantly inhibit the political system of land and emergency management, social security, human welfare, and the economy.

In recent decades, several studies have illustrated how the probability of a flood event occurring can be modified by human-dependent factors such as climate change and land use, among others.

For this reason, over the past decade, flood risk management policies have evolved to redirect the actions of policymakers from purely physical defensive measures toward integrated management and planning strategies. They place greater emphasis on the complexity of the interaction between social and physical processes.

The complexity of physical processes lies in the wide variety of underlying phenomena that produce different types of flooding. The complexity of social processes lies in their characterization by human-related factors such as risk perception, emotions, bonds, context, actions, and related behaviors.

Structuring the complexity of these two systems could support flood risk management because it would help to define the elements that describe the phenomenon and more precise measures through which to mitigate it.

This integrated approach to risk management is the result of a common scientific understanding of structural problems over traditional management strategies, which have neglected the multi-agent and systemic nature of risk, characterized by high complexity and uncertainty, defined in terms of individual objectives with problem-solving approaches and top-down management strategies.

Building on these premises, this study seeks to contribute to existing research based on bottom-up approaches aimed at supporting planning decision-making for flood management.
Specifically, It provides a preliminary evaluation and framework of citizens' perceptions and knowledge of flood risk, in order to assess the attitude of protective behavior and useful elements to support planning decision-making for flood management. Finally, it has been tried to identify a potential implication of the methodology on the field of urban planning.
The proposed methodology is the result of a research experiment developed through different approaches applied to two case studies: Brindisi and Bari.
It is given by the combination of an electronic survey to collect data on citizens' perceptions of flood risk, a structural equation model (SEM) to structure them, and a hybrid choice model (HCM) to link citizens' perceptions of flood risk and knowledge of measures to actions and thus define citizens' behavior under different risk scenarios.
The results of the present study show that risk perceptions are closely related to knowledge regarding the causes of the phenomenon. They significantly influence citizens' attitude to protective behavior under risk conditions, although to different degrees. In turn, risk perception depends more on previous experience while knowledge depends on factors such as residence, level of education and level of risk communication.
The methodological approach allowed useful elements to emerge to support planning decision making for flood management.

KEYWORDS: Flood Risk Management; Urban Planning; Risk Perception; Protective Behavior; Hybrid Choice Models.

EXTENDED ABSTRACT (ITA)

Gli effetti delle inondazioni sull'ambiente urbano sono considerati tra le principali cause di crisi sociale, in quanto sono in grado di influenzare drasticamente lo stato socioeconomico di una comunità. Un aumento degli eventi può inibire significativamente il sistema politico di gestione del territorio e delle emergenze, la sicurezza sociale, il benessere umano e l'economia.

Negli ultimi decenni, diversi studi hanno illustrato come la probabilità del verificarsi di un evento alluvionale possa essere modificata da fattori dipendenti dall'uomo, come, tra gli altri, il cambiamento climatico e l'uso del suolo.

Per questo motivo, nell'ultimo decennio, le politiche di gestione dei rischi di inondazione si sono evolute per reindirizzare le azioni dei responsabili politici da misure difensive puramente fisiche verso strategie di gestione e pianificazione integrate. Esse pongono maggiore enfasi sulla complessità dell'interazione tra processi sociali e fisici.

La complessità dei processi fisici risiede nell'ampia varietà di fenomeni sottostanti che producono diversi tipi di inondazioni. La complessità dei processi sociali risiede nella loro caratterizzazione, data da fattori legati all'uomo come la percezione del rischio, le emozioni, i legami, il contesto, le azioni e i relativi comportamenti.

Strutturare la complessità di questi due sistemi potrebbe supportare la gestione del rischio alluvione poichè aiuterebbe a definire gli elementi che descrivono il fenomeno e misure più puntuali attraverso cui mitigarlo.

Questo approccio integrato alla gestione del rischio è il risultato di una comprensione scientifica comune dei problemi strutturali sulle strategie di gestione tradizionali, che hanno trascurato la natura multi-agente e sistemica del rischio, caratterizzata da elevate complessità e incertezza, definito in termini di obiettivi individuali con approcci di problem-solving e strategie di gestione top-down.

Partendo da queste premesse, il presente studio cerca di contribuire alle ricerche esistenti basate su approcci bottom-up, finalizzate a supportare il processo decisionale di pianificazione per la gestione delle inondazioni.

Nello specifico, fornisce una valutazione preliminare e una strutturazione della percezione del rischio alluvione dei cittadini e della conoscenza delle misure di protezione, al fine di valutarne la conseguente attitudine al comportamento protettivo.

Infine, sono state proposte possibili implicazioni dell'adozione della metodologia nel campo della pianificazione territorial.

La metodologia proposta è il risultato di un esperimento di ricerca maturato attraverso differenti approcci applicati a due casi di studio: Brindisi e Bari.

Essa è data dalla combinazione di un'indagine elettronica per raccogliere dati sulla percezione del rischio di inondazione da parte dei cittadini, un modello di equazione strutturale (SEM) per strutturarli, e un modello di scelta ibrido (HCM) per collegare le percezioni del rischio di inondazione dei cittadini e la conoscenza delle misure alle azioni e quindi definire il comportamento dei cittadini in diversi scenari di rischio.

I risultati del presente studio mostrano che la percezione del rischio è strettamente connessa alla conoscenza relativa alle cause del fenomeno. Esse influenzano notevolmente l'attitudine dei cittadini al comportamento protettivo in condizioni di rischio, anche se in misura diversa. A sua volta, la percezione del rischio dipende maggiormente dall'esperienza pregressa mentre la conoscenza dipende da fattori quali la residenza, il livello di istruzione e il livello di comunicazione del rischio.

L'approccio metodologico ha permesso di far emergere elementi utili per supportare il processo decisionale di pianificazione per la gestione delle inondazioni.

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0.0 INTRODUCTION

Floods are among the most frequent and destructive natural phenomena on a global scale. Flood risk is among the main causes of social crisis, as it can drastically affect the socioeconomic status of a community, and an increase in flood events can significantly inhibit the political system of land and emergency management, social security, human welfare, and the economy (Rufat et al., 2015). According to studies by the World Resources Institute, global flood victims are expected to double by 2030, from 65 million to 132 million (Kuzma e Luo, 2020).

For these reasons, the effects of flooding on the urban environment and social vulnerability are challenging issues in flood risk management and long-term urban planning (Liao 2012).

In recent decades, several studies have illustrated how the probability of occurrence of a flood event can be modified by human-dependent factors, such as, among others, climate and land-use changes (Milly et al., 2002; Allamano et al., 2009; Salas and Obeysekera, 2014).

For this reason, flood risk management policies are evolving to redirect the actions of policymakers from purely physical defensive measures toward integrated management and planning strategies, placing greater emphasis on the complexity of the interaction between social and physical processes. (Schanze, 2006).

The complexity of physical processes lies in the wide variety of underlying phenomena that produce different types of flooding known as flash, coastal, fluvial, or pluvial floods (Bates et al., 2008), while that of social processes can be reconducted to their characterization, given by human-related factors such as risk perception, emotions, bonds, social and spatial context, and behaviors (Slovic et al., 2004; Santoro et al., 2019).

Evidence shows that these factors affect the communities' response to flooding risk and it is associated with the social context in which a specific flood occurs (Wickes et al., 2015). Indeed, according to Boholm (2003), the community's perception of risk and more generally its understanding of natural disasters is socially constructed. This assumes that citizens' response behavior is a part of a dynamic and adaptive decision-making process in which individuals and social factors interact (Slovic et al., 2004). Moreover, a wide range of sociodemographic characteristics, but also the psychological factor of risk perception and awareness, exposure, and communication techniques have been identified as factors affecting citizens' behavior (Miceli et al., 2008; Becker, 2014; Lechoskwa, 2018).

Even though these aspects are well known in the scientific field, at present their implementation in planning tools is still very limited (Bradford et al., 2012). The main reason lies precisely in the difficulty of structuring and characterizing social processes.

The characterization of the social processes could improve the effectiveness of flood risk planning strategies because it allows defining those elements that contribute to the risk reduction and preparedness of exposed communities. Correct behavioral responses to flooding events by communities can help to reduce damages up to 80% (Grothmann and Reusswig, 2006).

Understanding the social context through the way citizens perceive and respond to the flood risk is crucial to determine the social elements that could be considered to improve flood risk management (Miceli et al., 2008; Bradford et al., 2012; Bubeck et al., 2012; Fox-Rogers et al., 2016).

0.1 OBJECTIVE OF THE STUDY

Starting from that evidence, this work seeks to contribute to existing research on bottom-up approaches used to support decision-making for flood management.

Specifically, It provides a preliminary evaluation and framework of citizens' perceptions and knowledge of flood risk, in order to assess the attitude of protective behavior and useful elements to support planning decision-making for flood management. Finally, it has been tried to identify a potential implication of the methodology on the field of urban planning.

This approach that involved the indirect participation of citizens was strongly desired in this phase (planning / pre-event) to understand the perception of those who live in areas of risk, their acknowledgment of causes and effects related to risk, and their behaviors in conditions of flood risk.

Many studies in fact, (e.g. Fielding, 2012; Scolobig et al., 2012; Mondino et al., 2020) show that the population is often not aware of its exposure to flood risk, so increasing the exposure to the risk itself through their behavior. This can be reflected in the different nature of floods in urban areas (Bates et al., 2008), so leaving an open question about their correct definition already in a planning context (Liao 2012).

In a flood management process, understanding perception and related behavior allow increasing the possibility to develop more timely and effective flood risk management strategies both during the planning phase, through

models that can be implemented within the plans, and during the emergency phase (post-event).
To this purpose, the present research has structured the perceptual sphere of individuals and outlined their behavior in different risk scenarios, through the construction of agent-based statistical models.
The methodology was the result of a growing research experiment applied to two case studies: Brindisi and Bari. The limitations found in the methodology experimented on the city of Brindisi have been overcome in the case study of Bari. More details are in the following section.

0.2 PROCEDURE OF ANALYSIS

The methodology proposed within this research work, which finds full expression in the case study of Bari (Section 4) is the result of a path developed over time. It has been applied firstly to the Brindisi case study and then revised, implemented, and applied to the Bari case study.
In this path, the research questions have grown, increased, and become increasingly complex with the consequent search for viable paths.
In the first phase of the methodology, applied to the Brindisi case study, the work has tried to answer the question:

- *what are the elements influencing citizens' flood risk perception and knowledge in urban areas?*

This question led to carrying out a literature review that allowed to build a theoretical framework. This allowed to design an online interview called E-Survey.

The data collected and processed through statistical tools permitted to understand how citizens living in areas exposed to hydrogeological risk perceive the risk of flooding and to what extent they know the protective measures to deal adaptively with a future flood event.
The results obtained have given insights into the specific case study and have allowed the development of suggestions on possible measures to be taken or implemented in the planning tools.
This work adds up to the many studies of understanding of perception for different categories of citizens and represents a methodology of structuring perception and knowledge useful to the process of flood risk management.
The methodology used in this case study, based on structured E-Survey and data analysis through statistical tests, presented several advantages, among which the ease of collecting and analyzing data for the analyst and transmitting information to the decision-maker.
On the other hand, however, it did not allow to highlight prevailing elements of perception and to correlate perception to knowledge, related to actions to be taken.
For this reason, the present research subsequently sought to answer two other research questions:

- *Is it possible to identify factors that, more than others, affect the citizens' flood risk perception?*
- *Is it possible to correlate perception to action and to define the citizens' attitude to protective behavior in flood risk situation?*

The search for an answer to these questions has found an experimental application in the case study of Bari.

For the reasons stated, the articulation of the thesis, after the presentation of the two case studies, provides a parenthesis of the work carried out on Brindisi (in the process of publication) (Section 3). This is followed by the core research applied to the case study of Bari (Section 4).
Reflections and general conclusions close the work.

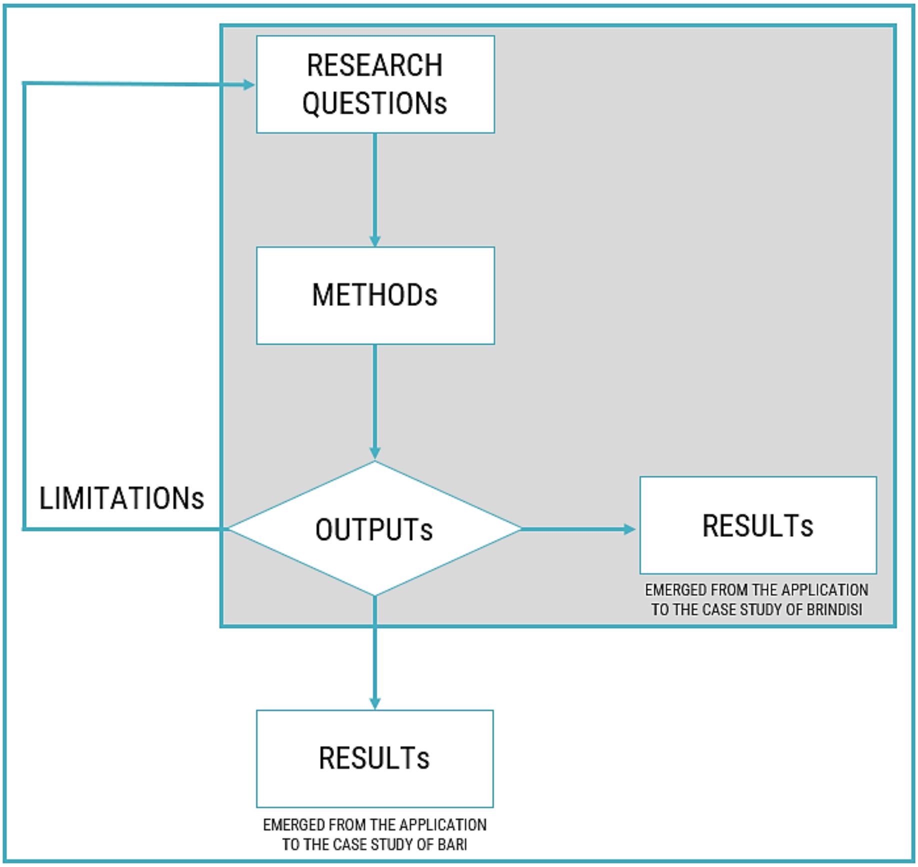


Figure 0.2 Methology workflow

CHAPTER 1: A REVIEW OF THE ROLE OF URBAN PLANNING AND DATA MODELLING TO SUPPORT FLOOD MANAGEMENT DECISION-MAKING PROCESS

According to a scientific agreement, the effect of human action on the natural environment leads to increased flooding. Specifically, referring to human-caused changes in land use, such as urbanization or deforestation among others (CSC Report 12).

Land use should be regulated by urban planning. It is responsible for governing the location of activities, land use types, scales of development, and design of physical structures and thereby decreasing the impact of flooding and subsequent damages (White & Richards, 2007; Neuvel & Van Der Knaap, 2010; Ran and Nedovic-Budic 2016).

Evidence shows that integrated urban planning with flood risk management represents a valuable tool for the long-term reduction (not structural) of human vulnerability and to increase the preparedness of the population to the phenomenon and its effects.

In the CSC Report 12 are reported virtuous examples of integration such as Japan, where the strategy adopted aims at adaptation through the control and guidance of community development; the French government is slowly implementing national risk prevention plans that regulate the use of land called. The risk plan divides the area into three planning zones where there are constraints in relation to the activities to be carried out. A bit like what happens in Italy by the constraints contained in the Hydrogeological Structure Plan (PAI).

The Australian government uses a planning matrix for flood risk. The matrix approach provides an opportunity to recognize that different land uses, densities, and forms of development have different vulnerabilities to flood risk. Land use can be planned in a variety of ways to achieve risk levels that meet the expectations of existing and future communities.

Although the potential of urban planning in the flood planning decision-making process is recognized, several practical obstacles prevent its implementation and integration into mitigation plans. The first step toward an approach to flood mitigation that integrates land use planning with flood risk management could be to involve as many stakeholders as possible to improve the quality and implementation of existing plans, thereby integrating structural and nonstructural measures (Baker Hincks, & Sheriff, 2010; Veraart et al., 2010).

Structural measures are defined as all those activities related to the construction and maintenance of levees, dams, mobile elements, and design control of the physical spaces of flood-prone areas (Kryžanowski, Brilly, Rusjan, & Schnabl, 2014; Neuvel & Van Den Brink, 2009).

Non-structural measures are defined as knowledge, practices, agreements and/or policies to mitigate flood risks or information and communication technologies (ICTs).

For example, decision support systems and geographic information systems inform decision makers with reliable information, such as hazard forecasts. These systems are communication tools that engage a range of stakeholders, as well as educational tools that increase public awareness (Price & Vojinovic, 2008).

Evidence from practice suggests that a combined approach between structural and non-structural measures is the most effective way to combat flood risk because it takes advantage of the individual strengths of the two approaches (Hall, Sayers, Walkden, & Panzeri, 2006; Hayes, 2004).

In fact, the advantage of structural measures is that they aim to provide physical protection to flood-prone areas, although their weaknesses are significant economic and environmental costs (Hall et al., 2006) and occasional failures due to inadequate planning and construction (Sills, Vroman, Wahl, & Schwanz, 2008). And resisting flooding by means of levees, dams, and channelization neglects the inherent uncertainties arising from human-nature coupling. Therefore, one must aspire to a resilience rather than resistance-based approach (Liao et al. 2012), including non-structural, cost-effective, and environmentally friendly measures. Their effectiveness is sensitive to socioeconomic context and government behavior (Dawson et al., 2011).

In a desire to move away from absolute reliance on structural measures and converge toward integration, policymakers in many countries are encouraging toward public-level actions through participatory processes that include communities (Bilkhzoch 2014).

These processes should be understood as a negotiation of shared responsibility among citizens, policymakers, and stakeholders for flood protection (Baan and Klijn, 2004; Terpstra and Gutteling, 2008; Kuhlicke et al., 2011; Burns and Slovic, 2012).

It is a highly complex process that depends on the intrinsic components of individuals (perceptions, knowledge, awareness), social relations among citizens and the cultural and legislative context, the ability to communicate and exchange information and knowledge, and the tools and methods of analysis and modeling that can help to do so (Mendoza and Prabhu, 2006; Voinov, 2010).

The study of this complex relationship between floods and society sees the emergence of several interdisciplinary frameworks, such as socio-ecological systems, complex systems theories, and sociohydrology (Liu et al., 2007; Werner and McNamara, 2007; Ostrom, 2009; Sivapalan et al., 2012; Srinivasan et al., 2012; Di Baldassarre et al., 2013; Montanari et al., 2013).

One of the most common methods for studying complex systems is based on statistical analysis of empirical research data such as surveys and interviews (Brown, 2007). In this context, interesting methods have been developed to combine the strengths of qualitative and quantitative data (Jick, 1979; Driscoll et al., 2007). The disadvantage of this method is related to data collection and analysis. If not properly structured, it becomes time consuming and burdensome.

Another method is agent-based modeling (e.g., Evans and Kelly, 2004). These models operate by prescribing interaction rules about individuals (identified as agents because they possess inherent characteristics). The disadvantage of these models is that they can become extremely complex and opaque (Turchin, 2003) and the results can be difficult to interpret and are often not generalizable (Janssen and Ostrom, 2006).

A third method that analyzes several assumptions about the fundamental processes and interactions that drive system complexity is formalized explicitly (in mathematical terms) using differential equations. The strength of this method is its transparency, flexibility, and ability to capture the dynamics that emerge from interacting processes. This type of modeling is useful when empirical data is limited (Brown, 2007). In addition, differential equations for dynamic modeling have been recognized as appropriate for understanding complex systems and are widely used in neoclassical economic models.

More recently, Van Emmerik et al. (2014) and Liu et al. (2015) have developed socio-hydrological models. This approach finds criticism from the social sciences on weak and robust social theories (Tainter, 2004) and little generalization of their applicability.
There are large gaps in our understanding of how human-physical systems function, and in this sense, model building is particularly valuable to explore how variables affect the functioning of human-physical system relationships and can aid in theory development (Brown, 2007).
In the present research work, two models were created. On the one hand, a Structural Equation Model (SEM) to formalize citizens' flood risk perception; on the other hand, a Discrete Choice Model (DCM) to associate citizens' flood risk perception with choice alternatives under different risk scenarios.
DCMs are used for modeling in many field of research: transportation sector, for evaluating transportation demand (see Hess 2005) or acceptability of stakeholder policies in urban freight transportation (see Le Pira et al, 2017); natural hazards, for hurricane evacuation route choices (see Cheng er al., 2008); Built Environment, for evacuation route choices (Huang et al 2008; Lovreglio et al., 2014; 2021) and in the field of applied geography, for modeling terrorist spatial decision making (Marchment et al., 2019).
In the field of flood risk management, DCMs are primarily used to understand the decision of the starting time for flood evacuation (see Lim et al., 2015), to examine homeowners' preference for different hazard mitigation options (see Frimpong et al., 2022), or to investigate individual preferences for long-term land use changes and the influence of policy choice recommendations on individual choice behavior (Ryffel et al., 2014).

Unlike DCMs, SEMs applied to flood management is less well known. Some examples can be found in the work of Renald et al., 2016 using SEM to assess the factors that influence the resilience adaptation model of the city of Jakarta, which is subject to constant flooding; Liu et al., 2017 using SEM to structure and investigate the direct and indirect factors affecting emergency evacuation capacity for rural households at risk of flooding; Hoang Ha Anh et al, 2018, who employed partial least squares structural equation modeling (PLS-SEM) to uncover the interrelationships among determinants of household vulnerability to flooding in Cambodia and the Mekong River Delta in Vietnam; Jega et al, 2018 using SEMs to examine farmers' risk perceptions, with a focus on the impact of floods on smallholder farmers' livelihoods and the extent of flood disaster management programs in Kelantan, Malaysia; Huang et al., 2020 using the SEMs to explore the quantitative relationship between socio-demographic factors, risk perceptions, and Flood protection behaviors. Wang et al., 2021 using SEMs to structure and measure the interaction between urban flood resilience and subdomain resilience (economic resilience, political resilience, human resilience, social resilience, institutional resilience, physical resilience and natural).

From a review of the literature in the field of flood management no attempts of structuring risk perception and knowledge through this approach were found.

This work therefore offers as an innovative element in the field of flood management, a preliminary assessment and framework of citizens' perceptions and knowledge about flood risk through the construction of SEM and DCM models.

The implementation of these two models will give rise to a Hybrid Choice Model (HCM) that allows to assess the attitude to protective behavior of citizens from their perception and knowledge. The outcome of the models will provide useful elements to support flood management decision making process and some implications for urban planning.

CHAPTER 2: CASE STUDIES

The choice to involve the cities of Bari and Brindisi is mainly related to three reasons:

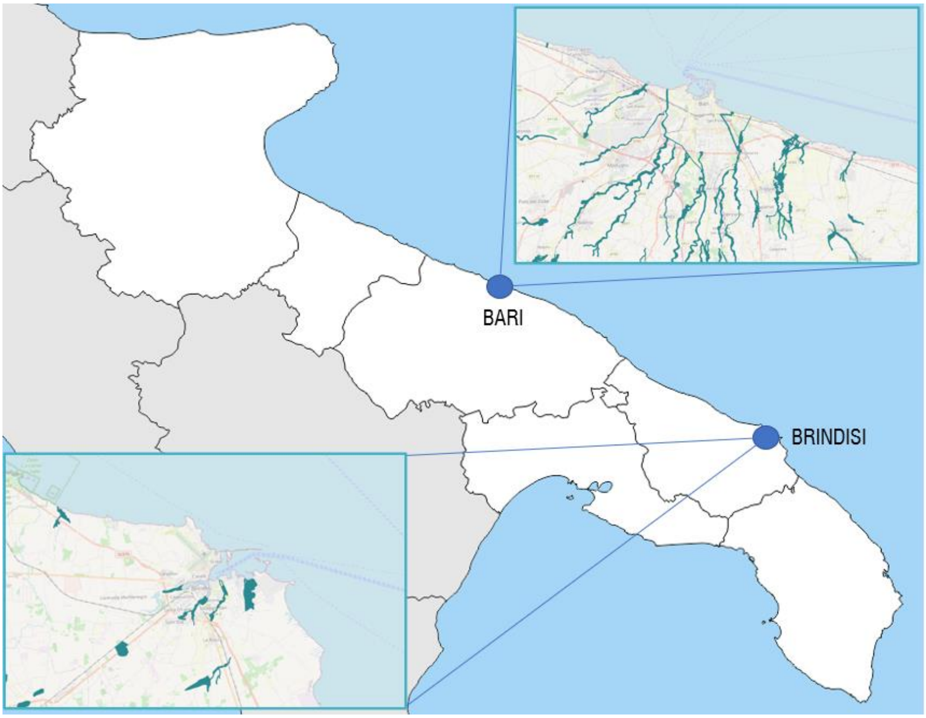


Figure 2.1 Flooding maps for an event with a return period of 30 years (in blue) (PAI, 2019)

(I) both municipalities are characterized, as most of the Italian territory, by phenomena of hydrogeological instability (Figure 2.1);

(II) in 2005 Bari e Brindisi have been involved in a flooding phenomenon that has caused extensive damage to the natural and anthropized territory, to the safety and health of citizens, and the economy. These aspects will be explained in detail in the following sections;

(III) geographic proximity has resulted in greater simplicity in carrying out the analysis and study.

A large part of the Italian landscape is sculpted by the action of rivers and the movements that occur along the slopes. Changes in the landscape, and in particular the most evident ones, often occur suddenly due to rare and particularly intense events (ISPRA REPORT 356/2021).

It can happen that a natural event, such as a landslide or a flood, interacts with humans and their environment causing damage. The concept of risk is therefore a consequence of an anthropocentric vision of nature and its evolutional processes. To understand the level of hydrogeological risk of a geographical area, it is necessary to consider organically a multiplicity of natural and anthropic factors. Heavy atmospheric precipitations are only the "triggering cause" of existing situations that were already previously unclear and precarious (Mossa 2021).

This work tries to structure the interconnections between existing human and physical factors to understand the complex issues that interfere with each other and provide useful suggestions for risk management.

Specifically, while human factors will be structured and modeled, there will be no hydraulic modeling at this stage. Existing data sourced from a variety of sources will be used, as explained in the following section.

2.1 BRINDISI

Brindisi is a coastal city located in the southeastern part of the Puglia region (Southern Italy) with a population of more than 85,000 inhabitants.

Figure 2.2 Brindisi city

2.1.1 GEOGRAPHICAL ASSESSMENT

The settlement and development of this city were favored by a large natural inlet which was the ideal location for the presence of a natural harbor since the time of the Roman Empire. As reported in the Regional Landscape Masterplan (see Regione Puglia, 2013), its urban structure has historically favored the docking of ships.

In Fig.2.3 the urban zoning of the city and mainstream network are reported. Going from North-West to South-East, it is possible to recognize a) Canale Cillarese, a stream characterized by the presence of the homonymous embankment dam; b) Canale Patri, the stream mainly connected to the urban texture, and at the end, in the industrial area, c) Fiume Piccolo and d) Fiume Grande streams. It is possible to recognize how the central urban core is surrounded by Canale Cillarese and Canale Patri, which flow in the internal port.

Figure 2.3 Mainstream network: a) Canale Cillarese, b) Canale Patri, c) Fiume Piccolo, d) Fiume Grande

2.1.2 HYDROLOGICAL ASSESSMENT

The geological-structural structure of the Brindisi Plain determines the geometry and the characteristics of the underground water bodies, influencing both the circulation and outflow modalities to the sea, and the quantitative and qualitative characteristics of groundwater. It is possible to distinguish a deep aquifer in the carbonate mass, cracked and char-satisfied and supported at the base by the seawater of continental invasion; then follows the roof a superficial aquifer, located in the sandy-calcarenite formation of the middle-superior Pleistocene (Terraced Marine Deposits) and supported at the base by the Sub-Apennine Clay Formation.

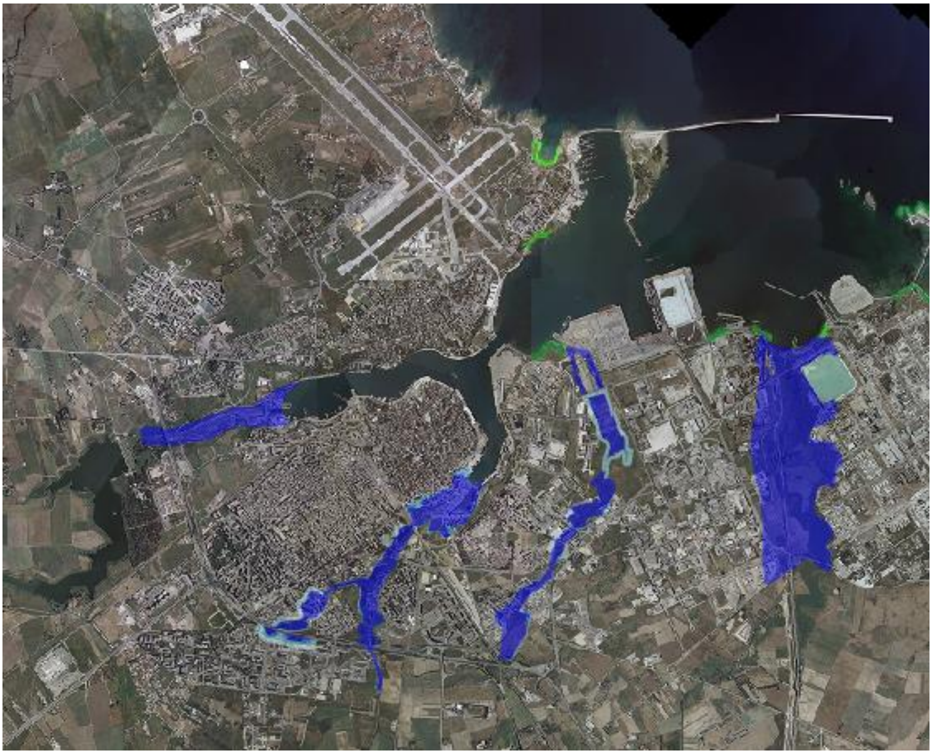


Figure 2.4 Flooding maps for an event with a return period of 30 years (in blue) (PAI, 2019)

Superficial and deep aquifers, except for some exceptions, are hydraulically separated from each other by the sub-Apennine Claybank, which is considered practically impermeable for hydrogeological purposes. The superficial aquifer presents generally modest water potentialities so that the

flow rates from it eligible with wells are modest. The only available water resource of importance in the Brindisi Plain is therefore present in the deep aquifer, whose hydrogeological characteristics have been investigated since the 1950s (COTECCHIA et alii, 1957; ZORZI & REINA, 1957; ZORZI, 1961).
The complexity of the hydraulic stream system is confirmed by Figure 2.4, where the flooding areas for an event with a return period of 30 years are reported (http://webgis.adb.puglia.it/gis/map_default.phtml).

2.1.3 FLOOD HISTORY

A preliminary analysis of the flood occurrences was conducted exploiting the AVI dataset (Guzzetti et al., 1994) and integrating floods information during the time interval between 1950-1999 by collecting data from local newspapers, recording 65 flood events news. Among others, each record contains the following information:

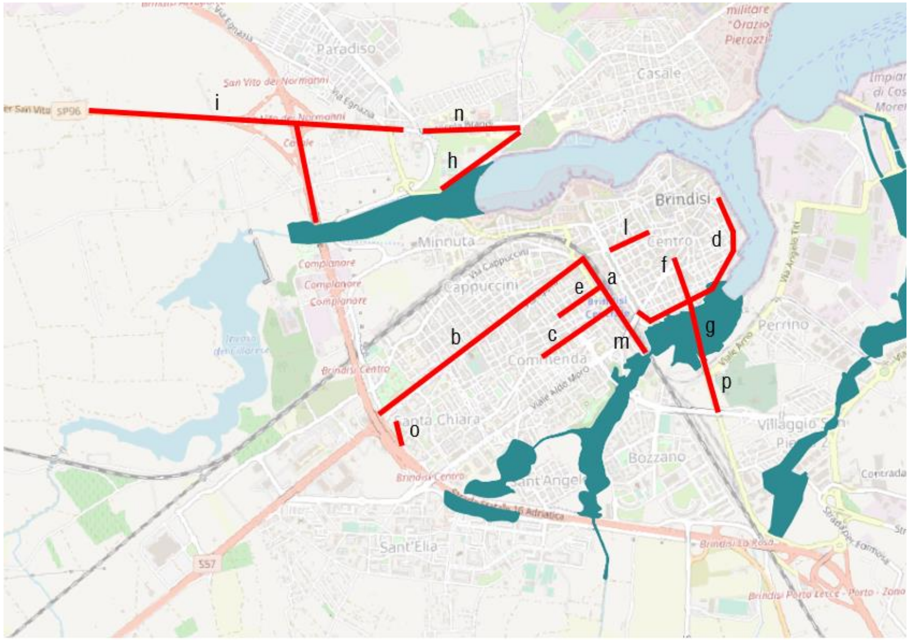
- the amount of daily rainfall;
- if a stream was indicated as responsible for floods (and their names);
- involved streets and/or neighborhoods (and their names);
- observed/estimated water depths.

In Table 2.1, the number of citations of flood events in newspaper articles is reported (when greater than 3), while in Figure 2.5 their position is illustrated.

Table 2.1 – Census of flooded streets reported by local newspapers

Landmark	Street name	Neighborhood	Number of Events (1951-1999)
a	Via Torpisana	Commenda	18
b	Via Appia	Cappuccini	10
c	Via Commenda	Commenda	10
d	Via del Mare	Centro	8
e	Via Imperatore Costantino	Commenda	7
f	Via Porta Lecce	Centro	6
g	Via Bastioni San Giacomo	Centro	5
h	Via Ciciriello	Paradiso	5
i	Via Provinciale per S. Vito	Paradiso	5
l	Via Carmine	Centro	4
m	Via Liguria	Commenda	4
n	Via Nicola Brandi	Paradiso	4
o	Via Cinque Giornate	Santa Chiara	3
p	Via Provinciale Lecce	Perrino	3

Figure 2.5 Maps of the census of flooded streets reported by local newspaper



The figures below show a brief photo collection of the 2005 event.

Figure 2.6 Overflow Canale Patri

Figure 2.7 Flooding in via Tor Pisana (meteoweb. EU)

Figure 2.8 Flooding in via provinciale Lecce (Il quotidiano di Puglia.it)

Figure 2.9 Flooding in Viale Commenda (Brindisi Oggi. it)

2.2 BARI

The city of Bari is an Italian municipality of 313,164 inhabitants, and the provincial capital of the Apulia region (ISTAT 2021).

Figure 2.10 Bari city

2.2.1 GEOGRAPHICAL ASSESSMENT

It is subdivided into five districts which are characterized by highly permeable soil and a hydrographic network not always defined, composed of numerous erosive grooves called ‘lama’ (Figure 2.11).
In the field of geology, the concept of lama is classified as a shallow erosive furrow, typical of the Apulian landscape, which carries rainwater during heavy rain. In dry conditions, it is characterized by ground and debris deposited by erosive phenomena.

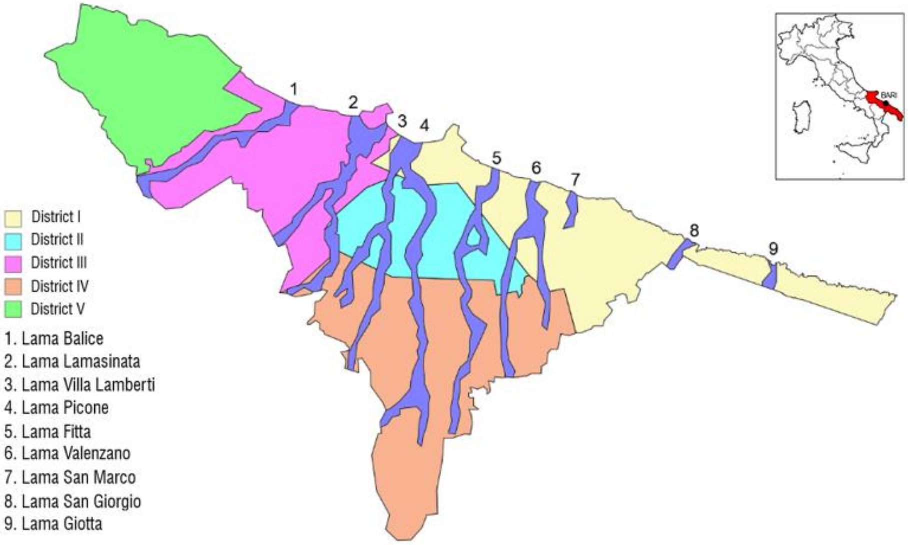


Figure 2.11 District and lame

2.2.2 HYDROLOGICAL ASSESSMENT

The municipality of Bari is part of the Adriatic sector of the Murge which, being a karstic territory, has an almost absent superficial hydrography mainly due to the permeability of the Mesozoic formations; in its place, there is a wide range of characteristic karstic forms (depressions, carted fields, blind valleys, blades, etc.). The Adriatic sector of the Murgia is characterized by the existence of a deep or main aquifer and secondary aquifers. The impressive water table, circulating in the carbonate masses, is called "deep" or "main" aquifer to distinguish it from the "superficial" ones located in the post-cretaceous soils.

The deep (or main) aquifer of our karst region does not circulate free-flowing, as it was believed until today and as it happens in the Salento Peninsula and the Gargano, but under pressure and very often at considerable depths below sea level; it is found at greater and greater depths proceeding from the coastline towards the more inland areas and rests on the seawater of continental intrusion.

The underground water circulation takes place both in a diffuse and in a concentrated way, this last situation is validated by the presence of the second stratum.

Secondary aquifers are located in rocky horizons that are particularly permeable compared to the poorly permeable or impermeable rock mass that contains them. They would have originated from the discontinuous alternation of practically impermeable rocks (marly limestone, marly clays, calcareous breccias, etc.) and horizons particularly permeable for cracking and karstification.

2.2.3 FLOOD HISTORY

During heavy rainfall, this natural erosive groove allows water runoff. However, when they are altered in their confirmation due to anthropic activities, they constitute a danger to the surrounding environment. This is the case for the city of Bari. Although there is historical evidence of flood events, e.g., the events of 1905, 1915, 1926, the development of the city has often occurred without respecting the conformation of the territory. Natural erosive grooves can often host cultivations of vines and olive trees and or even residential settlements (Mossa 2020).

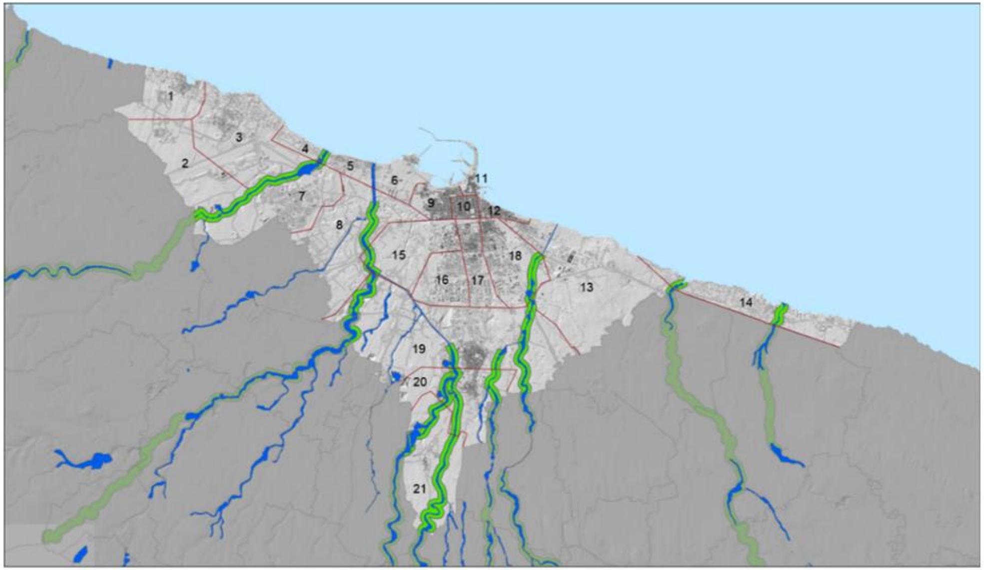
Because of the expansion of the city, the first flood coming from the Picone lama repeatedly swept away roads and buildings in 1905. The waters poured down the southwest side of the city, causing extensive damage, especially in several streets.
After only ten years, in September 1915, two impetuous alluvial currents, one coming from Cassano Murge and the other from Noci and Putignano annihilated the town again, causing more deaths and injuries. With the last nubifragio of 1926, they took finally the measures and they put in action plans for urbanization to prevent ulterior catastrophes.
Among these, the reforestation of a large area of the high basin of the Picone, corresponding to the current forest Mercadante di Cassano and from which it was believed prove-nicer floodwaters and was made a channel deviator: the so-called Canalone. And on that occasion, the autonomous fascist Institute for the popular houses commissioned engineer Giuseppe Favia for the project for the building of the condominium for the flooded people (Figure 2.12).

Figure 2.12 Building for flooded people

Some roads bring back memories of the effects (Figure 2.13)

Figure 2.13 Plaques in remembrance of the events

The most disastrous flood event, of the last 20 years, in terms of rain intensity, damage, and loss of life, that affected the city of Bari occurred in 2005 (Mossa 2010). In October 2005, due to the magnitude of the rainfall and poor land management, there were as many as 6 fatalities and extensive damage to buildings, businesses, crop fields, and roads (Flood risk management plan, Piano di Gestione Rischio alluvion, PGRA). Table 2 shows some of the damage as a consequence of this flood. In addition to the 2005 flood, several other flood events occurred in Bari in more recent years as reported in several newspapers. These events are summarized in Table 3.
From a quick visual analysis of Figure 2.14, it is easy to see that the flooded area (blue zone, PAI) is located near the nine natural incisions (green zone). Moreover, it is also possible to see that many neighborhoods (red boundaries) are affected by flooding areas.



1. Santo Spirito; 2 Catino-San Pio; 3. Palese; 4. Fesca; 5. San Girolamo; 6 Marconi; 7. San Paolo; 8. Stanic; 9. Libertà; 10. Murat; 11. Borgo antico; 12. Madonella; 13. Japigia- Sant'Anna; 14. San Giorgio-Torre a Mare; 15. Picone; 16. Poggiofranco; 17. Carrassi; 18. San Pasquale-Mungivacca; 19. Carbonara-Santa Rita; 20. Ceglie del Campo; 21. Loseto

Figure 2.14 Floodable area in blue with a return period of 30 years. Lama in green (PAI), red boundaries identified neighborhoods

Table 2.2 Damage of flood event, Bari 22/10/2005 (source: PGRA, IT_ITR161I020_La Gazzetta del Mezzogiorno)

Neighborhood/ Street	**Damages**
Santa Rita	Flooding of the ex CAVA DI MASO and BRANDONISIO; Flooding of roads, public parks, and productive settlements
Viale G. T. Liuzzi, Santa Rita, Ceglie e Carbonara	Flooding of roads
Via del Monastero	Flooding of productive settlements
Santa Rita, Via Donadonisi	Flooding of roads
Loseto, Via Cisterna di Terrarossa	Flooding of agricultural land
Ceglie – Modugno	Flooding of roads
Loseto, Via Cisterna di Terrarossa	Flooding of agricultural land
Strada San Giorgio Martire	Flooding of roads
Santa Rita, strada Fondo Capillo	Flooding of roads
San Giorgio	Two motorists ended up in the sea, one dead. The car swept by a 3m wave of mud was dragged for 3 km towards the sea.
San Girolamo	The sea unfolds in a radial pattern from the delta of the Lamasinata diverter channel, dragging debris, trees, pipes, and sheet metal with it.
Santa Caterina	Flooding of the cultivated olive groves inside the canal riverbed

Table 2.3 Damage of flood event in Bari after 2005 (source: online newspaper)

Flood date	Neighborhood/ Street	Damages	Source
26/04/2014	San Girolamo	Flooding of roads	Il Quotidiano Italiano
28/07/2014	Torre a Mare	Overflowing lama San Giorgio; Flooding of roads	Bari Today
08/07/2016	Picone	Flooding of the overpass station	Bari Today
15/07/2016	Palese	Flooding of the underpass station	Bari Today
15/06/2018	San Paolo, Libertà Old city	Flooding of part of San Paolo Hospital and part of the Palagiustizia and the Basilica of San Nicola	Repubblica
16/09/2018	Palese	Flooding of the underpass station	Bari Live
10/07/2019	Madonnella	Breaking of the Matteotti sewer on the waterfront	Bari Today
07/09/2019	Carbonara, via De Marinis	Flooding of roads	Gazzetta del Mezzogiorno
03/12/2020	zona industriale; Modugno, Carbonara; Libertà, Carrassi e San Pasquale	Flooding of roads	BariViva

Figure 2.14 shows that the neighborhoods at greatest risk are those to the north of the city, crossed by the lama Balice. Table n.2.3 confirms recent events in the Palese and San Paolo neighborhoods; Lama Lamasinata crosses five neighborhoods including San Girolamo, Stanic, and Carbonara, affected by recent events.
The central area of the city is characterized by the presence of three natural incisions (Villa Lamberti lama, lama Picone, and lama Fitta) that cross the districts of Carbonara-Santa ta, Ceglie and Loseto.
Finally, the southern part of the city is crossed by lama San Giorgio and lama Giotta that affect the neighborhood of San Giorgio, Torre a Mare, known for the events of the flood news. The figures below show a brief photo collection of the flood event.

Figure 2.15 Lama Picone after 2005 flooding event

Figure 2.16 Railway embankment after 2005 flooding event, Acquaviva Delle Fonti city (BA)

Figure 2.17 Collapse of the building of a company of the S. Rita flyway after 2005 flooding event

CHAPTER 3: ASSESSING FLOOD RISK PERCEPTION AND KNOWLEDGE OF PROTECTIVE MEASURES TO SUPPORT PLANNING DECISION-MAKING PROCESS FOR FLOOD MANAGEMENT. THE CASE STUDY OF BRINDISI (APULIA REGION)

This chapter is taken from the homologous article in press on Safety Science 2022; Authors: Santoro, S., Totaro, V., Lovreglio, R., Camarda, D., Iacobellis, V., and Fratino, U.

3.1 FACTORS AFFECTING FLOOD RISK PERCEPTION AND KNOWLEDGE OF PROTECTIVE MEASURES: A THEORETICAL FRAMEWORK

According to a common scientific understanding, risk perception consists of the interpretation of an event by citizens, and it is socially constructed (Boholm et al., 2003).

Risk perception can be defined as the process by which actual risk, composed of the combination of hazard, vulnerability, and exposure), is observed and internalized by each individual (Thistlethwaite et al., 2018).

In the last period, in the field of flood risk management, research on perception has increasingly sought to analyze influencing factors, investigating, among others, the link with human behavior and factors such as danger awareness (Sjöberg, 1998; Miceli et al., 2008), previous experiences (Weinstein et al., 1998; Lindell and Hwang, 2008; Leckowska 2018) and perceived responsibility in carrying out mitigation actions (Terpstra and Gutteling, 2009).

The perception of flood risk is also correlated with geographical characteristics, institutional and community factors, such as social dynamics, socio-economic aspects (Botzen et al., 2009), and participation and community trust in institutions (Weinstein et al., 1998; Renn and Rohrmann, 2000; Sjöberg et al., 2004, Miceli et al., 2008;), as well as the sociodemographic variables of age, income, education, or homeownership

(see a review of Leckowska 2018). A deep understanding of public perception is useful because allows one to understand how people act to reduce risk (Slovic and Peters, 2006; Xia et al, 2017).
An action can either amplify or reduce the risk depending on whether an individual engages in protective behaviors or not (see a review of Andráško et al., 2021). Therefore, a study of risk perception implies a necessary knowledge of the social context, of the community, and its relationship (Renn et al., 2000).
Knowledge, as reported by Weichselgartner & Pigeon (2015) has a dynamic nature that is constructed through social interactions. The data, information, and facts that each individual is processing. Knowledge creation does not occur simply by providing new data/information, but rather when that information is elaborated in the social process. According to Davenport and Prusak (1998), knowledge is "a fluid mixture" constructed through social interaction and experience.
In this study, knowledge was investigated in two ways. The first way is a dimension of perception. It refers to citizens' knowledge of the possible effects of the event; then, as a separate but related entity to risk perception, it refers to citizens' knowledge of protective measures.
To structure the perception and knowledge measures, in the present work the theoretical frameworks are defined as follows:
(i) the theoretical framework of flood risk perception has been built according to a literature review, and among others taking inspiration from the works of Renn and Rohrmann (2000), Renn (2000), and the review of Leckowska (2018). The choice to use as a bibliographic reference of Renn and Rohrmann (2000) and Renn (2000) from the field of psychology, has been used to investigate the main variables that influence the perception of risk, beyond the risk examined. On the other hand, Leckowska's review focused on the perception of flood risk, helped to confirm, implement, and

expand the variables that describe flood risk perception in the works of the last decades. It considers:

- cognitive dimension. It refers to subjective judgments of probability regarding the occurrence of a future flood disaster in the studied area and its consequences.

Subjective judgments on the probability of risk and concern have been considered as separate measures of risk perception as it happens in works such as (see Peters, Slovic, Hibbard, & Tusler, 2006; Sjoberg, 1998)

- awareness dimension. It refers to citizens' awareness predictability of a flood event; risk awareness can be defined as the knowledge of the presence of risk (Slovic, 1987);
- knowledge dimension. It refers to the degree of citizens' knowledge regarding the possible effects of the event on the city; In outlining the role of knowledge in disaster risk reduction (Weichselgartner & Pigeon 2015) clearly emphasize the dynamic character of knowledge, which is constructed through social interactions that shape the data, information, and facts that each individual is processing. Knowledge creation does not occur simply by providing new data/information, but rather when that information is processed.
- risk communication dimension. Citizens are asked for their opinion about the degree of effectiveness of risk communication. The effectiveness of a risk communication strategy is capable of increasing perception and awareness as demonstrated in the work of Bodoque et al., 2019.
- the dimension of trust towards public actions, existing measures, and public participation to reduce the flood risk in the city. The level of trust in authorities and public protection measures plays a significant role in shaping perception and the relationship with preparedness (Leckowska 2018).

In the text, these concepts are synthesized with the terms: Cognitive, Awareness, Knowledge, Risk Communication, and Trust.

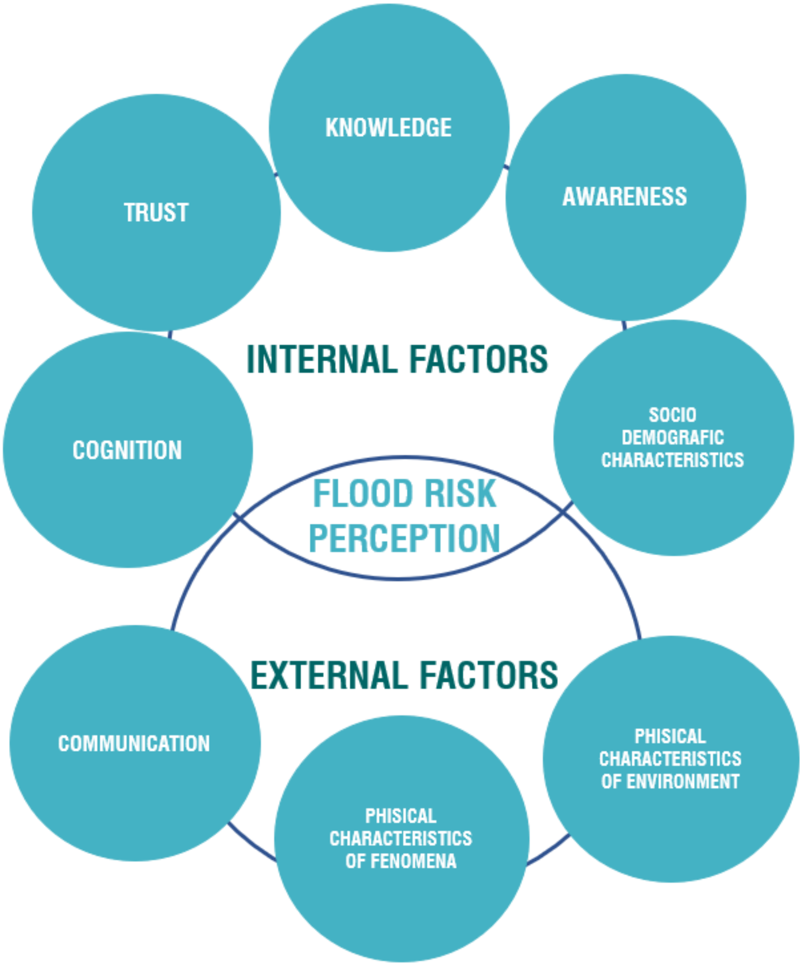


Figure 3.1 Theoretical framework

The dimensions of perception were divided as internal factors (intrinsic to individuals) and external factors (related to the relationships between individuals and the environment) as reported in Lovreglio et al.2020.

The dimensions of risk perception will be measured based on socio-demographic variables that characterize the user profile.
(ii) knowledge of protective measures: based on the Civil Protection Behavioural Guide. It suggests measures to be used before, during, and after the phenomenon, in open and closed spaces. The measures are published on the official website of the Civil Protection, Municipality of Brindisi.
The degree of knowledge will be measured according to socio-demographic variables that characterize the user profile.
The processing of this information allows us to better understand how citizens living in flood-prone areas may perceive flood risk and know protective measures and to demonstrate that it is possible to derive useful information elements to support the decision-making process for flood management through a bottom-up approach.
The perception analysis is characterized by high complexity because the risk is perceived differently for each citizen in a community (Renn and Rohrmann, 2000). Further, factors (especially social) contributing to risk definition, are not static over time and hard to be evaluated.

3.2 METHODOLOGY

The methodology proposes the combination of an E-survey to collect data regarding citizens' flood risk perception and preparedness knowledge and Mann-Whitney and Kruskal-Wallis test to analyze collected data (3.2).
The E-survey was built and shared using Google Modules, a free online tool. Significantly different from classical participatory approaches (see the revision done by Voinov and Bousquet 2010). Such use generally precludes the direct involvement of communities in the decision-making process but allows to acquire of information that

can be modeled downstream by the analysts (Voinov and Gaddis, 2008) and used in the decision-making process for flood mitigation.

The assessment of citizens' flood risk perception and knowledge of protective measures was carried out through statistical tests. Specifically, the Mann-Whitney test (MWT) allows measuring the variation of two independent variables among different socio-demographic categories (Mann and Whitney, 1947); the Kruskal-Wallis (KWT) test allows measuring the variation of more than two independent variables among different socio-demographic categories (Ostertagova et al, 2014). In both cases, the null hypothesis of these tests states that samples are drawn from the same distribution. In this work, the choice of the MWT and its extension represented by the KWT test for more than two independent samples (Wilcoxon 1945, Mann and Whitney 1947) was made because the data meet the requirements for the adoption of the test (Birnbaum, 1956): (i) the dependent variables (flood risk perception categories) are measured at the ordinal level (Likert scale); (ii) the independent variables are composed of groups (sociodemographic variables); (iii) there are no relationships between observations in each group or between the groups themselves; (iv) the variables are not normally distributed. Concerning flood risk perception analysis, due to many observations (perception categories), the Bonferroni correction was applied which is used to adjust p-values due to the increased risk of a type I error when performing multiple statistical tests (Armstrong, 2010).

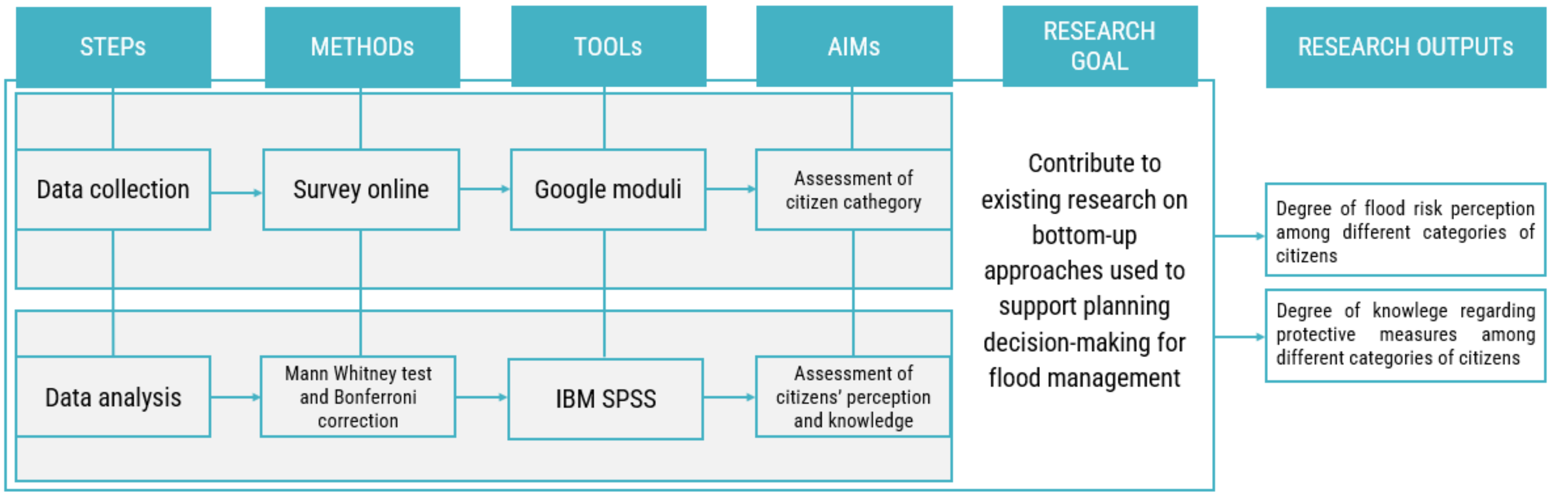


Figure 3.2 - Methodology applied

3.2.1 E-SURVEY DESIGN

Figure 3.3 E-survey logo

The E-survey was tested in two pilot sessions shared between November 2019 and May 2020. The first pilot test involved experts in the field of hydraulic and planning engineering, whereas the second one involved non-expert knowledge. The suggestions made by the participants after the first pilot test concerned the formulation of contents of some questions; some small changes were suggested from non-expert knowledge and concerned the understandability and reading of some questions (user acceptability).

Among the different data collection techniques, the E-survey has the advantage for the analyst to create a structured database and to boost the information collected through a wider audience using a web platform (Jansen et al. 2006), as compared to most typical citizen-techniques (Voinov and Bousquet, 2010). A well-structured survey can bring out not only the current state of society but can also provide indications of potential flood behavior and, therefore, be characterized by a predictive degree.

Sampling methodology belongs to the family of snowballing sampling, with the possibility of disseminating online surveys by using social media, telephone, and web site (Figure 3.4). Our choice was motivated by the exploratory nature of this work and to difficulties in reaching the population by another type of approach, finding an adequate balance with limitations typical of such approach (e.g., biased samples).

The choice to use an online tool as E-survey is justified by two main reasons: (i) the online tool aims to facilitate the collection of information through a broader audience than the normal participation techniques provided in the literature (workshops, seminars, paper interviews, door-to-door, etc.); (ii) the online tool allows for the collection of data in a more structured way than the citizen engagement methods mentioned above (Voinov et al.2016). On the other hand, the use of this methodology might have two limitations: (i) excluding the knowledge of citizens who do not use the web platform and (ii) providing results in an aggregated form that recognizes an "average" of citizens' perception.

Figure 3.4 Homepage of the website

The survey was composed of 40 questions and took between 15 and 25 minutes to be completed. The type of questions could be classified into closed questions, including multiple-choice, checkboxes, and ranking via Likert scales and open questions aimed at finding a subjective opinion about a particular described context. The questions were organized in four sessions to investigate: (a) citizen profile; (b) degree of citizen flood risk perception (c) degree of citizen knowledge regarding flood protective measures; (d) level of knowledge of space in case of flood evacuation.

For this study, data related to the profile of citizens and responses related to risk perception and knowledge of protective measures were used.

The questions were structured according to a Likert scale and investigated the dimensions of perception, as defined in Table 3.2. In addition, within this section, an open-ended question aimed to learn about the places in the city perceived to be most at risk by citizens.

The socio-demographic variables used to characterize the citizen profile are listed in Table .1. For this study, the first two sections relating to risk perception and knowledge of preparedness measures were analyzed (i.e., ii-iii).

Table 3.1 - Socio-demographic variable

Socio-demographic variables	**Description**
Gender	Male; female
Age	<18; 18-30; 31-45; 46-60; >60
Family composition	Number of family members; the presence of disabled people
Flood Experience	Previous experience
Hazard proximity	Living in a flood-prone area (neighborhoods)
Length of residence	Habitant, commuter

The degree of citizen risk perception has been investigated through factors that emerged according to a literature review (see Section 3.1).

Citizens answered questions for each dimension of perception (3.2). For each question, citizens were asked to express a preference on a Likert scale of 7 (1: not at all; 7: very much). It has also been introduced an open question asking which street in Brindisi was perceived by the respondent as being most at risk.

Table 3.2 - Items of the survey regarding risk perception

Dimension of risk perception	**Question**	**Question: select 1 to 7 according to your preference (1: not at all; 7: very much).**
Cognitive	1	How much could your neighborhood be exposed to flooding?
	2	How much flooding could be probable in your neighborhood?
	3	How dangerous could be flooding in your neighborhood?
Awareness	4	How much do you think a flood is predictable in Brindisi?
Knowledge	5	How much do you think you are informed about the effects of a flood in Brindisi?
Risk communication	6	How effective do you think is risk communication in Brindisi?
	7	How much confidence do you have in the actions of public administrations in Brindisi?

Trust	8	How much confidence do you have in the existing mitigation measures in Brindisi?
	9	How much do you believe in public participation as an approach to improve flood management?

Also, citizens were asked to select the recognized Flood Protection Strategies (FPS) from the set of alternatives in the Civil Protection Behavioral Guide (CPBG). The set of alternatives includes indoor and outdoor measures. The degree of citizens' knowledge regarding the FPSs provided in CPBG has been measured through a Likert scale. As before, for each measure citizens were asked to express a preference on a scale of 7 (1: not at all; 7: very much). The list of measures is shown in 3.3.

Table 3.3 - Items of the survey regarding preparedness knowledge

	Question: select 1 to 7 according to your preference (1: not at all; 7: very much)
Indoor measures	Do not get to the lower floors to secure your property
	Do not leave home to protect your car
	If you are in a basement room or on the ground floor, go up to the upper floors
	Avoid the elevator
	Turn off the gas and turn off the electrical system
	Do not go drinking water from the tap
	Restrict cell phone use: keeping lines free makes rescue easier
	Keep yourself informed on how the situation evolves and follow the indications provided by the authorities

Outdoor measures	Moving away from the flooded area
	Reach the highest neighboring area quickly
	Be careful where you walk: there may be chasms, potholes, open manholes, etc.
	Avoid using the car
	Avoid underpasses, embankments, and bridges
	Reduce cell phone use: keeping lines free makes rescue easier
	Keep yourself informed on how the situation evolves and follow the indications provided by the authorities

3.2.2 PARTICIPANTS

The survey was filled out by 301 citizens. Table shows that the gender of respondents is quite homogeneous (59% male, 41% female). The most representative age of the people sample is between 30 and 60 years. 17% of participants are under 18 because the survey was also disseminated among students. Most respondents live in a four-person household where there are no people with disabilities. 68% of respondents have never had any direct experience with flooding. 42% of citizens live in flood-prone areas. The neighborhoods have been subdivided into flood-prone and non-floodable areas according to Hydrogeological Management Plan maps for an event with a return period of 30 years (PAI, 2005) (Table 3.5).

Table 3.4 - Sample characteristics

Socio-demographic variables	**Description**	**Percentage**
Gender	male	59%
	female	41%
Age	<18	17%
	18 - 30	13%
	31-45	24%
	46-60	25%
	+60	21%
Family composition: number of family members	1	9%
	2	22%
	3	20%
	4	42%
	≥5	7%
Family composition: presence of disabled people	No	85%
	Yes	14%
Flood Experience	Yes	31%
	No	68%
Hazard proximity	Live in a flood-prone area	42%
	Live in the non-floodable area	57%
Length of residence	Resident	75%
	Commuter	25%

Table 3.5 - Neighborhoods subdivided according to PAI (2005) flood-prone areas

Neighborhood	Flood-prone area	
	YES	NO
Bozzano	x	
Cappuccini		x
Casale		x
Centro	x	
Commenda	x	
La Rosa		x
Minniti	x	
Paradiso	x	
Perrino	x	
S. Chiara		x
S. Angelo	x	
Sant'Elia	x	
Sciaia		x

3.3. RESULTS AND DISCUSSION

The following section is divided into three parts. The first two are related to the results and discussions on risk perception (Section 3.3.1) and preparedness measures (Section 3.3.2). In each subsection, the results are compared with others coming from the literature. The third part (Section 3.3.3) proposes a summary of the results and some suggestions to support the planning decision-making process for flood management.

3.3.1. RISK PERCEPTION

This section illustrates the results related to citizens' flood risk perception. The nine scores regarding the flood risk perception (see Table 3.2) provided by the respondents were analyzed to identify heterogeneities using the socio-demographic variables listed in Table 3.1.

The Table 3.6 shows the MWT and KWT p-values compared with a Bonferroni corrected level of significance ($\alpha=0.006$ with Bonferroni correction, i.e. $0.006 = 0.05/9$) related to flood risk perception.

While the values reported in Table 3.6 show the significance of the data referred to each question about the variables, they do not allow assessing the specific nature of each variable unambiguously. More detailed information emerges from boxplot visual analysis in Figure 3.5 which has been generated only for statistically significant variables. The visual analysis of the boxplots reveals interesting information on the distribution of populations, ensuring a direct interpretation of their differences and a distribution concerning a central value. For example, we have tried to understand the difference of perception referred to the gender variables, male and female, in question n. 3, 5, and 7, and so on for each category of sociodemographic variables. The presence of

disability in the family does not seem to influence in any way the perception of flood risk and for the sake of simplicity discussion of statistical tests output will be carried

The cognitive dimension refers to questions 1, 2, 3 (Table 3.2).

Observing the boxplots in Figure 3.5 it is possible to observe that among the results the cognitive component of those who live in areas at risk is significant.

They appear to have a higher perception than those who do not live but there is a not negligible perception even in areas where there is no source of risk.

Table 3.6 MWT and KWT p-values for risk perception analysis
(bold font is for statistically significant values, α=0.006)

Socio-demographic variables	**Question**								
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
Gender	0.033	0.012	**0.000**	0.052	**0.000**	0.061	**0.000**	0.032	0.073
Age	0.021	**0.000**	0.012	**0.000**	**0.000**	0.071	0.012	0.013	0.042
Family members	0.072	0.021	0.042	0.083	**0.000**	0.072	0.102	0.063	0.061
Disabled people	0.032	0.053	0.061	0.051	0.072	0.053	0.042	0.013	0.051
Flood Experience	0.021	0.043	0.032	**0.000**	0.112	**0.000**	**0.000**	**0.000**	0.021
Hazard proximity	**0.000**	**0.000**	0.022	0.012	**0.000**	0.043	**0.000**	**0.000**	**0.000**
Length of residence	0.063	0.021	0.082	**0.000**	0.063	0.112	**0.000**	**0.000**	**0.000**

Further confirmation of what is stated is visible through
Figure 3., where the answers of the citizen about the question "select the street in the city you perceive most at risk" is reported. For example, Tor Pisana and Cappuccini (landmark 1, 2
Figure 3.) are the most perceived landmark at risk, even if they are not in flood-prone areas. Such information could help the decision-maker to investigate the nature of the flood in these areas. A greater justification can be found via Perrino and via Appia (landmark 3, 4,

Figure 3.). The reason for these results can be found in the fact that the city of Brindisi is located in an area characterized by a groundwater aquifer with low permeability and porosity, and whose dynamics in response to short and intense rainfall cause a raising of the water table implying flooding of depressed areas and hydrogeological risk (Spizzico et al., 2006).

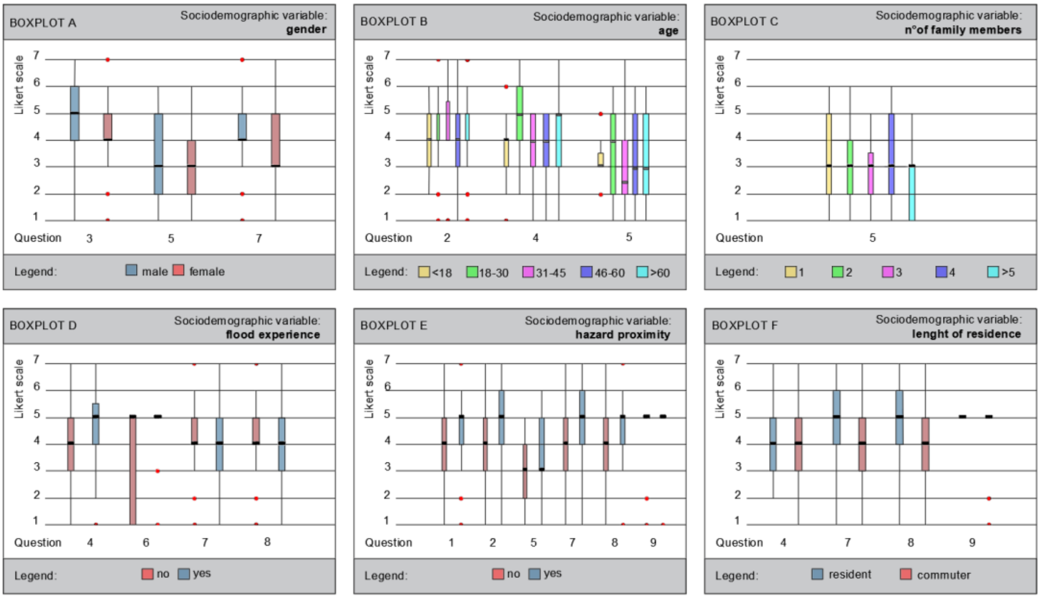


Figure 3.5 – Boxplots of statistically significant risk perception variables

Moreover, another interesting dimension related to the values of the medians between those who live in flooding areas and those who live outside the risk areas (boxplot e, Figure 3.5). These values differ from a minimum of 3 to 5 on the Likert scale. This type of information could allow the planner to understand whether those living in risk areas underlie the risk (Wachinger et al., 2012). This behavior is well-known in the literature because prolonged exposure tends to underestimate the effects by creating a mechanism known as "risk bias" (Apel et al., 2009).

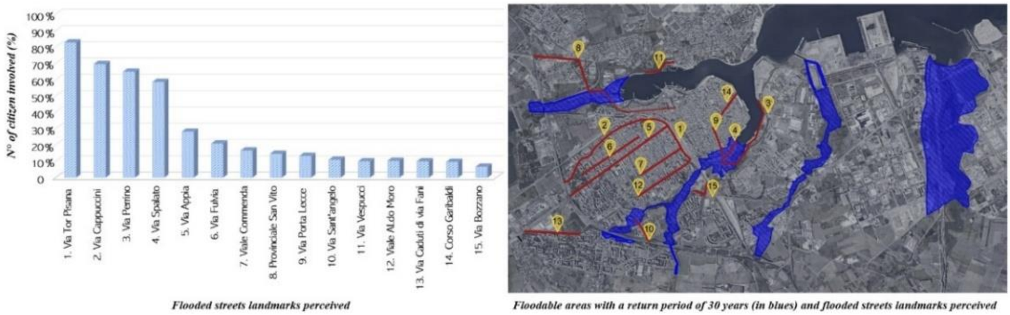


Figure 3.6 Landmarks of perceived flooded streets

The awareness dimensions s represented by question n.4 (Table 3.2). The average awareness is rather low except for the 18-30 and >60 classes. It is significant for those who have had previous experience and does not seem to make a difference if one is a permanent or commuter.

The knowledge dimension is represented by question n.5 (Table 3.2). About age, it is possible to observe a higher median value for the category 18-30 (boxplot b, Figure 3.5). Through this result, a decision-maker could interrogate the mode of communication tools and act with more precise actions to reach all age groups. In addition, it is interesting to note that the demographic variables of gender and hazard proximity have also emerged in this case. A consideration that could be useful to the decision-maker is the fact that those who live close to stream networks can have predictive abilities that modify their perception.

The effectiveness of the communication measures has been confirmed only in the case of those who have had experience (31% of respondents). It is interesting to note that the effectiveness is verified positively, and there is no dispersion. The results obtained from this study have been confirmed by the literature. Many studies question the role of communication in risk management. Since the beginning of the last twenty years, Renn (2008) stresses the importance of adapting risk communication to people's specific needs. In this way, people are made easier to judge their risk situation and make informed decisions based on personal preparation and security measures. Effective communication, or its absence, can have a great influence on how people are prepared for a disaster. Also, recent studies confirm these findings (Arai 2013; Medford-Davis and Kapur, 2014; Bradley et al. 2014).

3.3.2 KNOWLEDGE OF PROTECTIVE MEASURES

This section illustrates the results related to preparedness. Table shows the MWT and KWT p-values evaluated with a Bonferroni corrected level of significance ($\alpha=0.025$ with Bonferroni correction, i.e. $0.005= 0.05/25$) related to protective measures. In Figure 3. instead, boxplots for statistically significant variables are reported.

Table 3.7 - MWT and KWT -values for preparedness knowledge analysis, (bold font is for statistically significant values, $\alpha\leq0.025$)

Socio demographics variables	**Category of measures**	
	indoor measures	outdoor measures
Gender	**0.025**	0.415
Age	**0.000**	**0.000**
n° of family members	0.095	**0.000**
presence of disabled people	0.355	0.085
Flood Experience	0.455	**0.000**

Hazard proximity	**0.000**	0.255
Length of residence	**0.005**	**0.020**

As a first note, it is shown that also, in this case, the presence of disabled people in the family group is not statistically relevant. Figure 3. shows that median values for each category and both measures of knowledge are generally lower than 4, whereas maxima reach the value of 5. This demonstrates a generally low-medium level of preparedness diffused across all categories.

From Table 3.7, it is possible to note as the null hypothesis of the corrected tests is rejected for both indoor and outdoor measures, demonstrating a homogeneity in gap distribution.

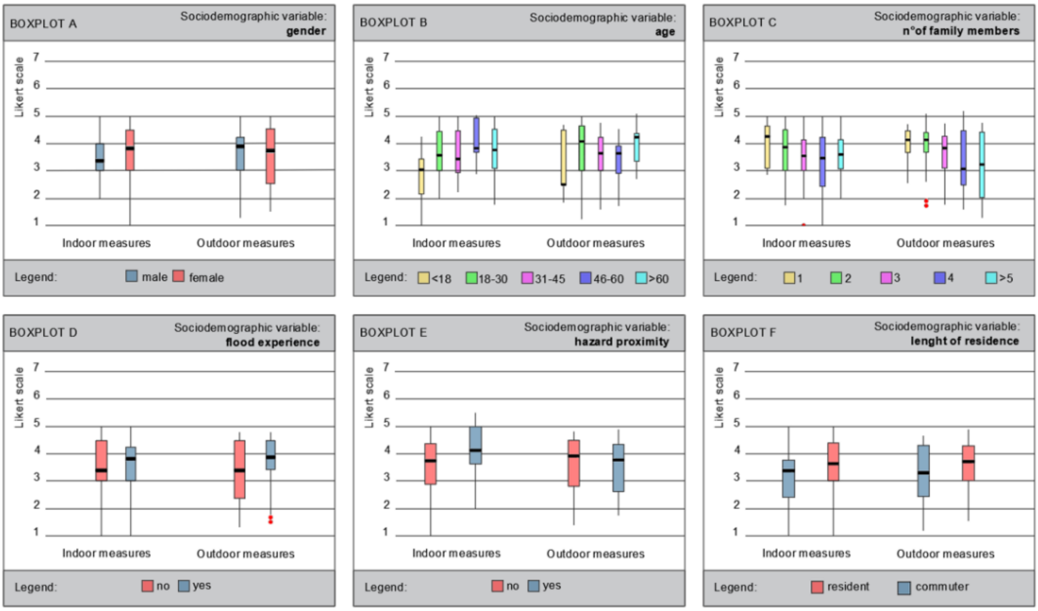


Figure 3.7 - Boxplots of knowledge of protective measure variables

In the case of age category, the weak class is the youngest one, and the reason can be traced back to the lack of experience, besides not adequate information at the school level. On the other side, results of the length of residence variable for indoor can be motivated by the residential factor. People who live in Brindisi show a greater knowledge of measures, and this difference is marked for outdoor activities, probably due to an experience factor. This statement is confirmed by the positive output of the statistical tests for outdoor measures for flood experiences and indoor measures for hazard proximity. These results are not in contradiction; being plausible to assume that the greater knowledge of outdoor measures is linkable to direct experience, boosted to the different types of floods, while hazard proximity role in shaping indoor measures for the high level of risk due to river floods.

Results of this step of our survey analysis are particularly interesting because they can inspire identifying gaps in implemented flood risk management strategies and, at the same time, able to give tangible elements to institutional agents for planning future ones.

As remarked before, there is a generally low-medium knowledge of safety measures. This is a relevant issue because one of the main abilities of this approach is in drawing out societal fragilities, leading to a better characterization of the population. For example, the survey shows how sensitive categories are young people and families concerning inadequate outdoor measures knowledge. Consequently, it can be remarked that, in case of flood, they are more susceptible to higher exposure to flood effects.

3.3.3 RESULTS SUMMARY AND SOME SUGGESTIONS TO SUPPORT FLOOD MANAGEMENT DECISION-MAKING PROCESS

To understand the effectiveness of the bottom-up approach to support decision-making for flood management, the results were sorted, and contextually suggestions placed temporally, spatially and according to specific categories of citizens were proposed.

The identification of variables that influence community heterogeneity can be useful for policymakers, disaster managers, and several practitioners who must coordinate and communicate with different levels of government, classes of actions, and at various times in the disaster management cycle. To this end, using the methodology applied in this paper, it is possible to classify risk reduction actions temporally, spatially, and according to specific categories of citizens (Table 3.8).

Table 3.8 - Time positioned suggested flood mitigation measures

TIME POSITIONED	MAIN RESULTS OF RISK PERCEPTION AND KNOWLEDGE OF PROTECTIVE MEASURES	NON STRUCTURAL MEASURES	AIM OF MEASURES
PRE-EVENT	The perception of flood risk is lower for women while they have a higher knowledge of indoor measures; commuters and citizens without previous flood experience have a low perception of risk and little knowledge of preparedness measures.	Promote participatory processes and forums open to citizens	to decrease the gap of perception and knowledge between different categories of citizens
			to increase collaboration between public and private sectors to inform commuters (workers and students) about the flood risk areas
			to involve those who have previous flood experiences to allow the transmission of memory

People between 18-30 represent the age group with the highest perception of flood risk. People under 18 represent the age group with the least perception of risk. Preparedness is characterized by an inversely proportional relationship between family group size and knowledge.	Improve communication strategies	to evaluate the effectiveness of the alert means used so far (as well as their knowledge), measuring the degree of trust of people in institutions to calibrate in a manner consistent with the target user (for example, school seminars to reach under 18s; social channels for > the 40s; social campaigns on local TV, in the streets for >60s) taking care to ensure its effectiveness by ensuring its reception and clarity;
People who live near streams have a higher flood risk perception of risk and knowledge of preparedness	Manage public interventions	to evaluate the presence and the effects of different types of flood on the territory, thus validating the current

measures. The flood risk perception of people who live in areas where there is no source of risk is not negligible. They have low knowledge of the preparedness measures.

works of mitigation of the risk and appropriately calibrating the communication of measures;

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to improve integrated risk management: the implementation of a communication strategy that can contemplate the transmission of measures in other types of risk (e.g., seismic), describing the usefulness of individual actions and avoiding the occurrence of overlapping information;

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to obtain scenarios on the behavior of the population capable of improving the predictive ability on the possible behavior of the agents during the event;

DURING EVENT	Areas of the city perceived to be more at risk have emerged	Improve the management of alert techniques and risk communication	Taking targeted action of civil protection activities
POST-EVENT	Working in the planning phase means reducing the possibility of major effects in the recovery phase (post-event). Knowing citizens' perception and knowledge of the measures allows them to better respond to the event in an effective way. It can be done for example using: - the provision of special areas of population convergence that take into account the possible behaviors and conflicts of the population (both social and individual), providing appropriate relief and support measures; - the efficient management of economic relief measures for those affected by the flood; - the preventive planning of technical interventions necessary to restore the regular flow of water;		

3.4 FINAL DISCUSSION

The applied methodology aims to structure the planning phase for flood risk reduction starting from the elicitation of citizens' flood risk perception and knowledge of protective measures. The results show that this methodology can become a useful tool for planning risk mitigation activities.

According to a review by Kellens et al. (2013), most studies regarding flood risk perception are characterized by an exploratory nature and there isn't a theoretical framework available in social science research. As a result, there is no methodological standardization in measuring and analyzing people's flood risk perceptions and their adaptation behavior.

In this study, the methodology based on the combination of E-survey to collect data regarding citizens' flood risk perception and of protective measures and statistical tests to analyze collected data, has been applied due to: (i) exploratory nature of investigation, (ii) difficulties in reaching and completely define the population and (iii) impossibility of disposing of adequate financial and human resources for carrying out an opportune statistical sampling.

Findings related to knowledge of measures appear to be in alignment with the literature. Many studies provide evidence that even if individuals have experience and a high perception of risk, they rarely adopt adequate knowledge and preparedness actions (Bradford et al., 2012) (Siegerist M. et al, 2006; Hall TE et al, 2009; Scolobig, A.et al, 2012). The link between perception and protective behavior appears to be very weak (Bubeck, P et al, 2012; Wachinger et al, 2012), if at all (Miceli R. et al. 2008).

In Section 3.1.1 and 3.2.2 homogeneities in investigated population categories were investigated, highlighting their main characteristics and distributions. This led to several considerations about the origin of the responses and helped us in a deeper understanding of the social and environmental framework.

A complete description of boxplots need to be supplemented by dwelling on their outliers. The importance of these points arises by considering the lowest of them as system weaknesses, potentially related to a not negative impact of flood events. These consequences cannot be only categorized as of direct type (borrowing the terminology from the field of damage assessment) but can affect other spheres of human being, as that psychological.

Psychological consequences are more complicated to be treated, are related to the personal status of each person, and can be influenced by other factors connected with their own life. Pieces of evidence of post-flood psychological diseases were documented in different studies (Krug et al., 1998; Clemens et al., 1999; Gordon et al., 2011; Alderman et al., 2012; Lowe et al., 2013). In this way, E-Survey has been useful for detecting potential situations of psychological unease, which can eventually degenerate in a post-event illness, and that can be due to a low perception of care from institutions, which should support people with immaterial assistance.

Moreover, thanks to E Survey it has been possible to collect data regarding the perception of risk communication. The results can help practitioners and policymakers in defining adequate strategies for improving communication on the correct way of behaving by combining information highlighting gaps in risk communication and knowledge of measures. As reported by Renn (2005), it is critically important to tailor risk communication to people's specific needs. This facilitates and maximizes the decision-making process of people acting on preparedness and personal safety measures.

This work relies on the use of traditional statistical testing to investigate the heterogeneity in risk perception and preparedness knowledge by testing the null hypothesis: the distributions of both populations are equal. This was achieved by investigating if and how multiple demographic variables and hazard proximity influenced the answers for the nine items measuring the risk perception and the two items measuring the preparedness knowledge. The Bonferroni correction was adopted in this work to mitigate the risk of a type I error (i.e., the mistaken rejection of a null hypothesis) when making multiple statistical tests. This approach has the limitation of increasing the chance of having a type II error (i.e., the mistaken acceptance of the null hypothesis) (Armstrong, 2014). However, this correction should be considered when a large number of tests are carried out in this work without having a priori hypotheses (Streiner & Norman, 2011). This was the case for this study, as multiple tests were carried out without pre-planned hypotheses aimed at confirming existing theories or conceptual models. On the other hand, this approach might have increased the change not to identify some factors explaining the heterogeneity in risk perception and preparedness knowledge (i.e., type II error) in the data used in this work. As such, further investigations are required to identify theories and conceptual models which could explain such heterogeneities in the Puglia region and to define well defined a priori hypotheses to be tested, together with a proper assessment of the statistical power of tests

3.5 CONCLUSIONS

This study aims to understand how citizens living in areas exposed to hydrogeological risk perceive floods risk and to what extent they know protection measures to adaptively address a future flooding event. This paper seeks to contribute to the field of research that addresses bottom-up approaches to support the decision-making process for flood management through a bottom-up approach. To achieve this goal, an E-survey was developed to collect variables describing citizens' flood risk perception and degree of knowledge of protective measures, and statistical tests were used in a post analyzing collected data.

Specifically, E-survey aims to collect data regarding citizens' flood risk perception and knowledge of protective measures and the Mann-Whitney and Kruskal-Wallis test to analyze collected data.

The degree of citizens' flood risk perception has been investigated through five dimensions of risk perception subdivided into Cognitive, Awareness, Knowledge, Risk Communication, and Trust.

The degree of citizens' preparedness knowledge was gathered by asking citizens to recognize flood protection strategies from the Civil Protection Behavioral Guide.

The results show that flood risk perceptions are strongly linked to variables such as trust in institutions, institutional communication, and information as well as among citizens. This is even more reflected in the categories aged less than 18 years and below. The presence of disabled people in the household does not act in any way in either perception or adaptation; previous experience, about flood perceived risk, plays a role in the awareness dimension alone while about knowledge of protective measures, it is slightly higher for those who have experienced the event. In addition, a slightly higher perception emerged for those living in risk areas, but the results of the remainder show that there is a non-negligible perception even where there is no source of risk. This is reflected in the different nature of the floods that have affected the city and should serve as input for policymakers to carry out investigations about the latent risks.

The E-survey methodological approach has the advantage for the analyst to create a database to be checked and analyzed in a short time, information to be spatially localized, and data to be used for more accurate analyses. Elements that would improve the flood risk management process by planning more precise strategies focused on specific categories of citizens according to their demography and location in an urban area at risk.

On the other hand, the use of this methodology may have two limitations: (i) excluding the knowledge of citizens who do not use the web platform and (ii) providing results in an aggregated form that recognizes an "average" of citizens' knowledge and perception. While the former might be addressed by relying on a larger consideration of more traditional, in-person investigation methods, aiming at implementing a hybrid integrated approach, the latter limitation could be more effectively dealt with only by using a more disaggregated, inclusive, and refined methodology. In this concern, a reference to multi-agent models, as developed from intelligent systems science, will be investigated starting from recent literature in the field of environmental resource management and planning at large.

CHAPTER 4: FROM PERCEPTIONS TO ACTIONS. AN HYBRID CHOICE MODEL TO UNDERSTAND CITIZENS' PROTECTIVE BEHAVIOR IN FLOOD RISK SITUATIONS. THE CASE STUDY OF BARI (APULIA REGION)

4.1 FACTORS AFFECTIVE PROTECTIVE BEHAVIOUR: A THEORETICAL FRAMEWORK

From a literature review, flood risk perception can be defined in different ways (see a review of Bubeck et al., 2012). However, there is scientific agreement that there are variables that can amplify or reduce risk perception. This is highlighted by the review of Bubeck et al., 2012; the study of Wachinger et al 2013, and also confirmed in the Leckowka 2018 review and several subsequent studies (e.g., Martins et al., 2019; Rana et al. 2020; Ullah et al., 2020; Roder et al., 2020; Hudson et al., 2020; Ge et al., 2021; Peng et al., 2020, among others). For example, the factors that influence the perception of flood risk are demographic factors, social factors, social status, environmental factors, the cognitive and experiential sphere, risk communication, and the role of memory. Flood risk perception considers multiple variables, such as knowledge, experience, values, attitudes, and emotions, which change depending on the nature of flood risk, the risk context, the personality of the individual, and the social context (Wachinger et al. 2013).

As in the previous section, the theoretical framework proposed in Figure 3.1 was also taken into account in this section. It was implemented with additional recent literature (Table 4.1) from which the methodology applied for this case study is inspired.

Compared to the methodology proposed in section 3, some dimensions of perception are treated differently:

- cognitive dimension that refers to subjective judgments of probability regarding the occurrence of a future flood disaster and its consequences, have been considered as an integrated measure of risk perception as it happens in the work of Bubeck et al. 2012;
- awareness dimension, that refers to citizens' awareness predictability of a flood event has been considered directly correlated in the direct experience variable as demonstrated by the work of Mondino et al. 2020;
- the concept of knowledge has been extended not only to the citizens' knowledge regarding protection measures but also to the causes of the phenomenon. The relationship between perception of risk and knowledge of causes is fundamental according to what is reported by Botzen et al. 2009, Raaijmakers et al. 2008 and Działek et al. 2013.

Table 4.1 Indicative references that examine flood risk perception (2018-2020)

Authors	Study area
Delin Liu et al., 2018	Henan Province, China
Wang et al., 2018.	Jingdezhen City, China
M. Diakakis et al.2018	Attica region, Greece
Roder G. et al., 2019	Veneto region, Italy
Shao W., et al., 2019	Alabama, USA
J.M. Bodoque et al. 2019	Navaluenga, Spain
Martins et al. 2019	S. Vicente, Cape Verde
Papagiannaki et al., 2019	Greece
Ullah F. et al., 2020	Khyber Pakhtunkhwa, Pakistan
Rana, I.A., et al. 2020	Pakistan
Chinh C. Ngo et al., 2020	Vietnam

Considering perceptions of risk in flood management is important because evidence shows that the communities' response to flood risk is associated with them (Wickes et al., 2015). A wide range of sociodemographic characteristics, but also the psychological factor of risk perception and awareness, exposure, and communication techniques have been identified as factors affecting citizens' behavior (Miceli et al., 2008; Becker, 2014; Lechoskwa, 2018).

Literature shows many studies regarding citizens' protective behavior towards flooding (Kellens, Terpstra, and De Maeyer 2013). Grothmann and Reusswig (2006) introduced Protection Motivation Theory (PMT). PMT indicates that motivation to protect oneself from a specific threat depends on how a person balances threat assessment with coping. These two processes are referred to as Threat Appraisal and Coping Appraisal (Fig 4.1).

Rogers (1983) indicates a potential interaction between the two processes: a high threat assessment along with a high coping assessment lead to protective behavior. If a high threat assessment meets a low coping assessment, however, protective motivation remains low. In a later study, Rippetoe and Rogers (1987) introduce protective and non-protective response types. While the former reduces the physical risks of a specific threat, the latter type of response (e.g., denial, fatalism, and avoidance) reduces only the emotional consequences of the threat.

This theory has been revisited by Babcicky and Seebauer (2019). They extend the methodology with the statistical technique of Structural Equation Modeling (SEM), which allows to capture the PMT components in their full granularity and comprehensively test their predicted interrelationships.

PMT and some key components have also been applied in flood hazard research (Richert, Erdlenbruch, e Figuireres 2017; Dittrich et al. 2016; Le Dang et al. 2014; Zaalberg et al. 2009; Grothmann e Reusswig 2006).
The creation of our model fits into this context of innovation by being partially inspired. In fact, based on the model SEM constructed previously, in this phase, it takes into consideration what in the PMT is defined as Threat appraisal. More details are provided in methodology section 4.2.1.

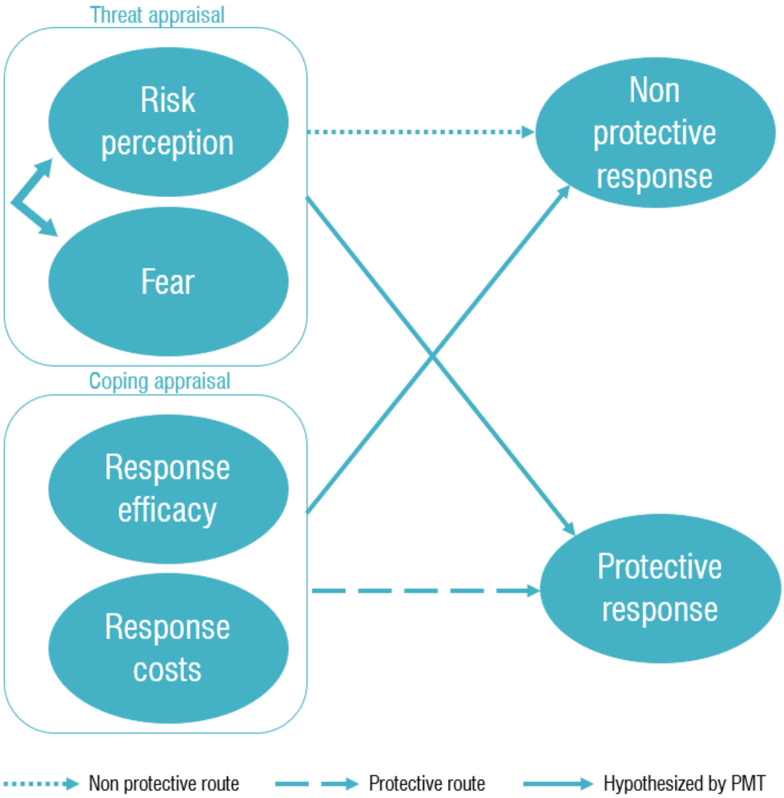


Figure 4.1 The structural model according to the PMT

4.2 METHODOLOGY

The methodology proposes the combination of an E-survey to collect data on citizens' perception of flood risk, a Structural Equation Model (SEM) to structure them, and a Hybrid Choice Model (HCM) to connect citizens' flood risk perceptions to actions and thus define citizens' behavior in different risk scenario (Figure 4.2).

The E-survey was built and shared using Google Modules, a free online tool.

The assessment of citizens' flood risk perception was carried out through the SEM building.

The SEM model applies a theoretical framework, defined after a literature review, to the case study, verifying its validity in real conditions. The results of our model are in line with the model hypothesized from the reports found in the literature.

Citizen flood risk perceptions are linked to actions through the Hybrid Choice Models (HCM). It connects the SEM model to actions defined within four risk scenarios, defined as the description of a possible risk event.

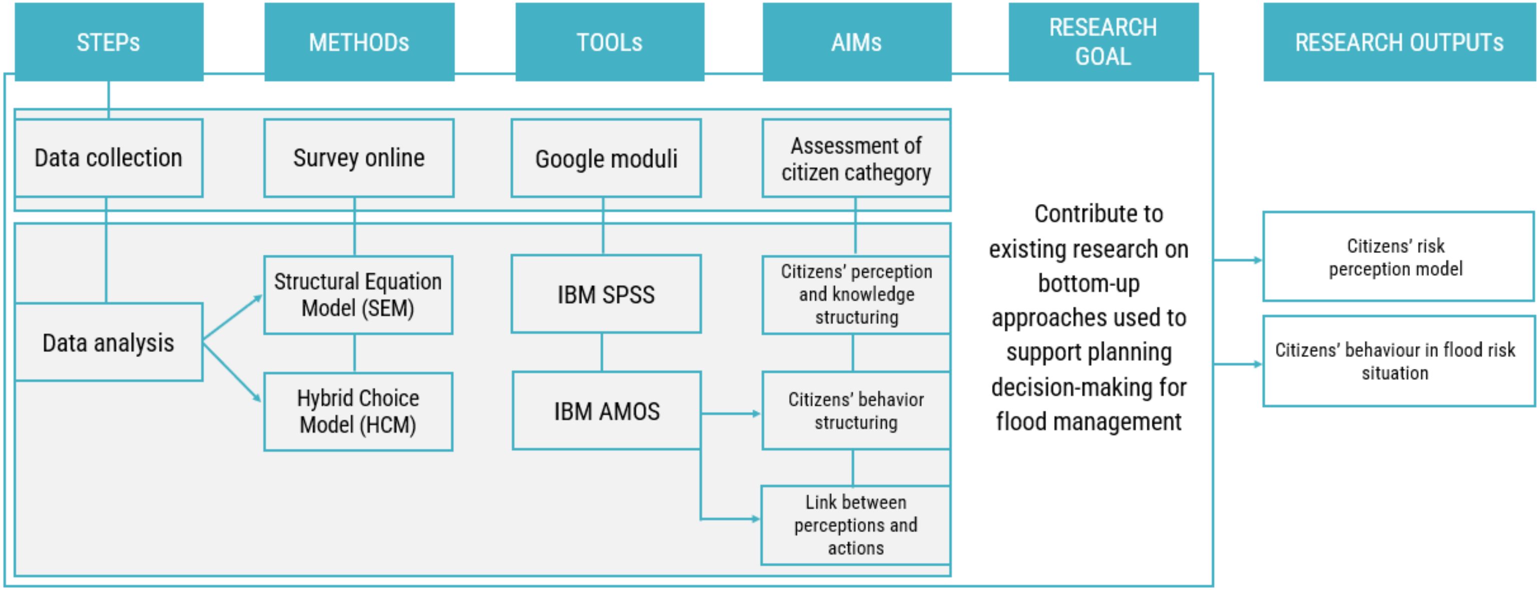


Figure 4.2 Methodology applied

4.2.1 E-SURVEY DESIGN

To collect data regarding flood risk perception, the E-Survey was structured into 33 questions subdivided into five sections: questions related to the demographic characterization starts the E-Survey (age, gender, income, etc.); the second section aims to know the risk perception of citizens in terms of knowledge of the event and measures, effects given by experience and probability of occurrence (likelihood) and its damages perceived (severity); section three aims to investigate the memory of past events; section four investigates the role of communication tools in emergencies; in section five, participants were asked to describe their behavior in a series of flood scenarios in an urban setting.

Most of the questions are closed-ended, with single, multiple, and/or Likert scale response options. Alternating with these are open-ended questions. For this study, four Likert scale questions were used to build the model (Table 4.2).

For this first part of the work, i.e. the construction of the SEM model, four questions have been used. The first question is designed to understand the degree of exposure perceived by citizens. Perceived risk exposure measures the expectation of being exposed to a flood, and the severity, i.e., the expected damage if an event occurs (Terpstra 2011, Bubeck, Botzen, and Aerts 2012). This type of information could allow the decision-maker to investigate on different spatial scales, the difference between perceived and real risk.

The second question aims to understand the degree of knowledge of defense measures in the three phases of a hazard (pre-event, during the event, and post-event). This type of information would help the decision-maker to evaluate the choices to be made in the different phases of the hazard cycle;

Question three is aimed at understanding the degree of trust in government instruments and institutions. This element would help the decision-maker understand the willingness of citizens to listen and adopt measures suggested from above.
The fourth question is aimed at understanding the degree of knowledge of the causes that generate the flood event. This information could help the decision-maker to control inappropriate actions by citizens (e.g., abusive activities).
The E- survey design was tested in two stages with two pilot studies. The first stage involved expert knowledge in the field of hydraulic engineering and design. The second one involved non-expert knowledge: citizens. The suggestions advanced after the first phase has regarded the formulation of the contents of some questions (technical acceptability); the suggestions advanced after the second phase has regarded the comprehensibility and the reading of some questions (user acceptability).
A set of four questions closes the survey. Each question in this set coincides with a risk scenario:

- scenario one describes a flood risk situation where the individual is involved by driving the car;
- scenario two describes a flood risk situation where the individual is involved on foot;
- scenario three describes a flood risk situation where the individual is asked to choose whether to save the car;
- scenario four describes a flood risk situation where the individual is asked to choose whether to save their home.

To make it easier to read the risk situation, the narrative description was accompanied by an image.

The risk scenarios are associated with two responses classified, according to PMT theory, as protective response and non-protective responses. In the model building, the former is associated with a value of 0. The latter is assigned a value of 1.
For each scenario, participants were asked to respond by their perception of risk in the situation described (Figure 4.3).

4.2.2 PARTICIPANTS

An E-survey in the city of Bari was conducted from September to December 2020. The survey was conducted using Google forms, a free tool available online. The choice to use an online tool is justified by two main reasons: (i) the online tool aims to facilitate the collection of information through a broader audience than the normal participation techniques provided in the literature (workshops, seminars, paper interviews, door-to-door, etc.); (ii) the online tool allows for the collection of data in a more structured way than the citizen engagement methods mentioned above (Voinov et al.2016).
The survey was designed for an open audience. The generality and number of respondents are not established a priori, as the questionnaire was open to all those who, upon learning of the research, voluntarily participated. Dissemination took place through two modes: (i) telephone snowballing and (i) online banners. Snowballing allowed dissemination among known people (Voinov et al.2016); banner, allowed to reach unknown people. An online link was created for both modes of dissemination
In addition, a dedicated website was created within which the purpose of the questionnaire was explained, and the research team was introduced (https://inondazionibari.webnode.it/) and advertised through various online channels. The sample that participated in the present study consisted of 752 citizens with the characteristics as shown in Table 4.3.
In the model, these variables will represent the observed variables.

Table 4.2 Content of E-survey

Dimension of perception	Question	Item	n. item
Risk perception (Likelihood)	Indicate how exposed you are to a flood	In your district	1
		In your city	2
		In your neighborhood	3
Risk perception (Severity)	Indicate the degree of damage due to the flood	In your district	4
		In your city	5
		In your neighborhood	6
Knowledge of measures	Indicate your level of knowledge about	Mitigation measures	7
		Protection measures	8

		Post-event measures	9
Trust in planning strategies	Indicate, according to your perception, the extent to which the following activities contribute to reduced flood risk	Urban planning	10
		Emergency planning	11
		Flood awareness and adaptation Programs	12
		Hydrogeological planning	13
Knowledge of flood causes	Indicate, according to your knowledge, the extent to which the following activities contribute to increased flood risk	The lack of hydraulic defense measures	14
		Building growth in constrained areas	15
		Improper sizing of the sewer system	16
		Climate changes	17
		Land morphology	18

Abusive activities	19
Waterproofing of natural areas	20
Lack of maintenance of sewerage System	21
Lack of activities' social prevention	22

Table 4.3 Variables description

Categories	Description	Percentage
Gender	Male;	57,66%
	Female	42,48%
Age	<18	0,00%
	19-30;	50,07%
	31-45	36,88%
	46-60	11,98%
	61-75	1,20%
Education	Elementary license	0,00%
	Middle school	1,07%
	High school	31,82%
	Bachelor's degree	18,11%
	Master's degree	34,49%
	PhD	14,65%
Income (per year_euro)	< 7.500	11,85%
	7.500-10.000	7,59%
	10.000-15.000	16,51%
	15.000-30.000	31,96%
	30.000-50.000	20,11%
	50.000-70.000	6,66%
	>70.000	5,33%
Household members	1	5,33%
	2	15,05%
	3	28,36%

	4	45,81%
	5	4,79%
	≥6	0,80%
Presence of children	Yes	21,97%
	No	78,16%
Presence of elderly	Yes	23,44%
	No	76,70%
Presence of disable	Yes	14,38%
	No	85,89%
Resident	Yes	49,67%
	No	50,47%
Experience	Yes	19,44%
	No	80,56%
Homeowner	Yes	59,25%
	No	40,75%
Hazard proximity	Yes	35,69%
	No	64,31%
Home type	Apartment building	84,69%
	Isolated house	15,31%
Living floor	Ground floor	38,09%
	Beyond the first floor	61,78%
Flood risk Communication	Yes	22,44%
	No	77,70%

Figure 4.3 Content of E -Survey regarding Flood risk scenario

Flood Risk Scenario 1	Description	Question	Value in the model
	The citizen is involved by driving the car	You are driving your car while an intense precipitation is hitting the city. The streets are completely flooded. Visibility and viability are compromised. What would you do?	
		- I would stay in the car and continue driving in search of a safe place	0
		- I would get out of the car and look for a safe place	1
Flood Risk Scenario 2	**Description**	**Question**	**Value in the model**
	The citizen is involved on foot	You are walking on the street as an intense precipitation is hitting the city. The streets are completely flooded. Visibility and viability are compromised. What would you do?	
		- I would stay where I am waiting for help to arrive	0
		- I would look for the first useful place to take protection	1
Flood Risk Scenario 3	**Description**	**Question**	**Value in the model**
	The citizen is asked to choose whether to save the car	An intense precipitation is hitting the city. The streets are flooded. Your car is parked on a flooded street and the water level is rising. What would you do?	
		- You would move it somewhere else	0
		- You would wait for the rainfall to end	1
Flood Risk Scenario 4	**Description**	**Question**	**Value in the model**
	The citizen is asked to choose whether to save the properties	Imagine you live on the ground floor. An intense precipitation is hitting the city. Water is coming into the house. What would you do?	
		- You would secure your possessions	0
		- Secure the entrances, shut down the systems and go upstairs	1

4.2.3 STRUCTURAL EQUATION MODEL BUILDING

Structural Equation Models (SEM) are multivariate regression models characterized by the fact that, in the same system of equations, each phenomenon involved in the network of causal relations covers the dual role of explanatory variable and response variable; therefore they appear very useful in the construction of a composite indicator. This approach is, by construction, deductive because the research scheme is not generated independently by an analysis of the data but is a consequence of theoretical considerations a priori, often qualitative and almost always suggested by experts in the field of application; it aims to quantify the strength of the links and possibly validate the significance.

It is a particular kind of modeling that encompasses a wide family of statistical methodologies and, specifically, can be considered the result of the fusion of two research traditions: Factor Analysis and Path Analysis.

Factor analysis consists of the analysis of a block of observable variables, highly covariant between them, for which it is assumed the existence of a common factor of which they are a manifestation, so it allows to describe the causal relationships existing between the variables. The researcher, after having ascertained the impossibility of establishing causal relationships highly covariant between them, tries to cancel what he considers to be a spurious link by introducing a common cause. The factorial approach (AF) goes back to the studies of Spearman (1904) who considered the controversial concept of human intelligence, articulating it as a "common component" present in all manifest variables, but difficult to measure. The idea of the British statistician is to combine the results obtained from specific tests on individual attitudes to arrive at a global assessment that will be assigned to the relevant latent concept or factor. In 1947, Thurstone introduced Confirmatory Factor Analysis (CFA) which proposed an analysis guided by a theoretical model based on a priori knowledge of the problem and integrated by a probabilistic apparatus capable of assessing the congruence between the theoretical consequences of the hypothesized model and the empirical data collected. Later, in the ‘50s and ‘60s, the statistician began collaborations with Wold, Duncan, and Goldberger, respectively, from which was born the study of causality links, i.e. Path Analysis.

The Path Analysis allows to estimate the magnitude and relevance of causal links simultaneously for all variables by providing information on their underlying latent structure, as well as overcoming the problems of covariation of explanatory variables and calculating indirect effects; in other words, it defines latent concepts, called latent variables (VL), not directly observable, through the use of variables, called manifest variables (VM), which, however, are measurable (Bollen 1989, Kaplan 2000). The development of this type of technique dates back to Wright (1921) who posed the problem of measuring causal links between variables and quantifying direct, indirect impact through path coefficients. At the beginning of the 70', the measurement models and causal models were recomposed in a single theoretical scheme through the use of structural equation models.

Structural Equation Modeling consists of two sub-models:

- the measurement model capable of defining latent variables, from manifest variables; in other words, it describes the relationships between VMs and VLs;
- the structural model that describes the causal relationships between the VLs. To fully understand its complexity, it is necessary to introduce some basic concepts and, specifically, the distinction between the concept of covariation and the concept of causation.

The covariation indicates a type of relationship in which two variables have a concomitant variation; this means that, as each variable changes, the variation of the other is associated.

Causation, on the other hand, indicates a type of relationship in which one variable is the cause and another is the effect whereby a change in the cause variable produces a change in the effect variable (Blalock, 1961). In particular, it implies the recognition of two other elements namely:

the directionality of action or asymmetry from one cause variable toward another effect variable;

the direct link between two variables in which the variation in one variable is due to, and not only associated with, the variation in the other variable.

In causal models, five different types of relationships can be distinguished:

- the direct relationship where the change in one variable (cause) produces a change in the other variable (effect), as shown in Figure 4.4 a;
- the reciprocal relationship in which there is no distinction between variable cause and variable effect, in how much the two variables influence themselves reciprocally, like illustrated in figure 4.4 b;
- the spurious relation where the covariation between the two variables is caused from a third variable, said variable of control, that acts on both like it are evidenced from figure 4.4 c;
- the indirect relation that binds the two variables in a causal relation, mediated from a third variable and representative of the tie, like is evidenced from figure 4.4 d;
- the conditional relation in which the relationship between the two variables depends on the value assumed from a third variable, as described in figure 4.4 e.

Another important distinction must be made concerning the terminology used for variables. In fact, in an SEM, variables can be both dependent and independent: what is an independent variable in one equation can be dependent in another, so we distinguish between endogenous and exogenous variables. The first ones are explained from the model and they can be, in the various equations of the same one, dependent

and independent, even if they must be dependent in at least an equation; the second ones must be independent in all the equations of the model. The SEMs can be represented using a system of equations to which a causal interpretation is given;
the equations are so many as many are the dependent variables in the model. Graphically, the models in the object are represented using the path diagrams, that they use the following symbology (Figure 4.5).

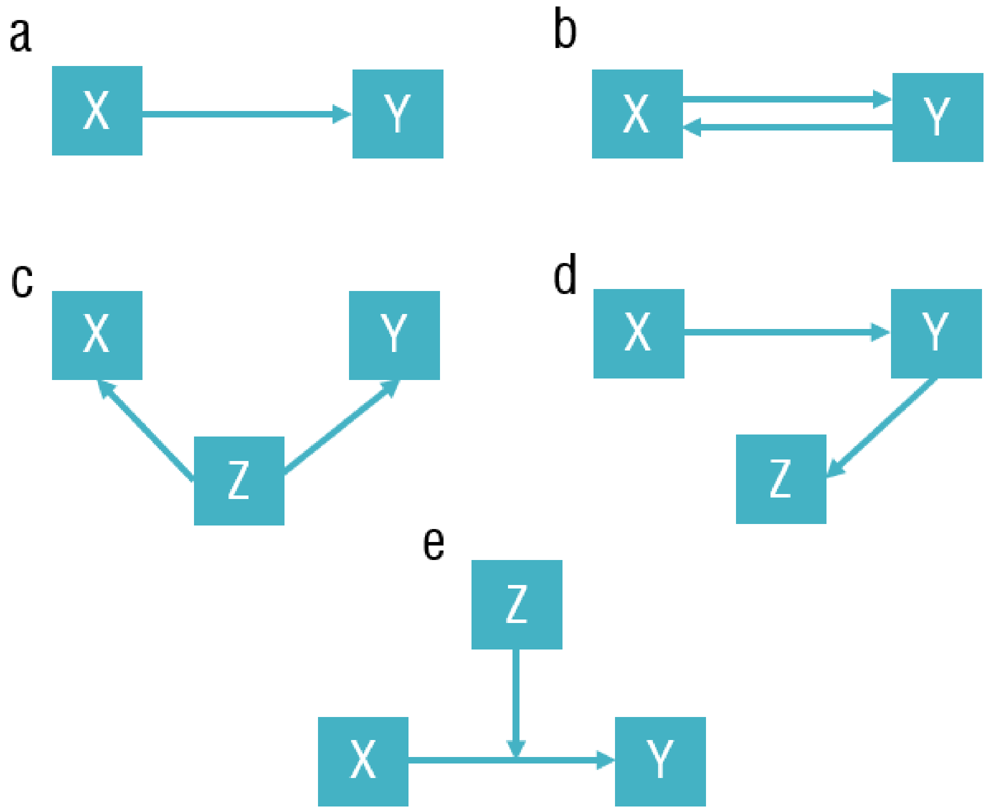


Figure 4.4 Type of relationship between variables

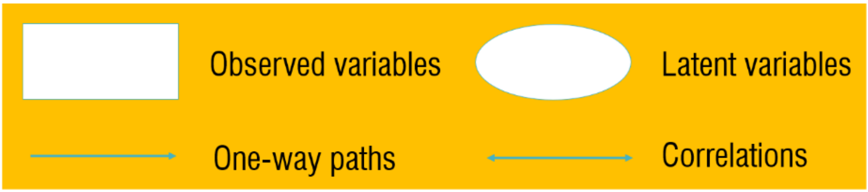


Figure 4.5 Path dyagram simbology

Observing the path diagram is immediately perceptible the distinction between the two models: the measurement model (green) and the structural model (yellow), (Figure 4.6).

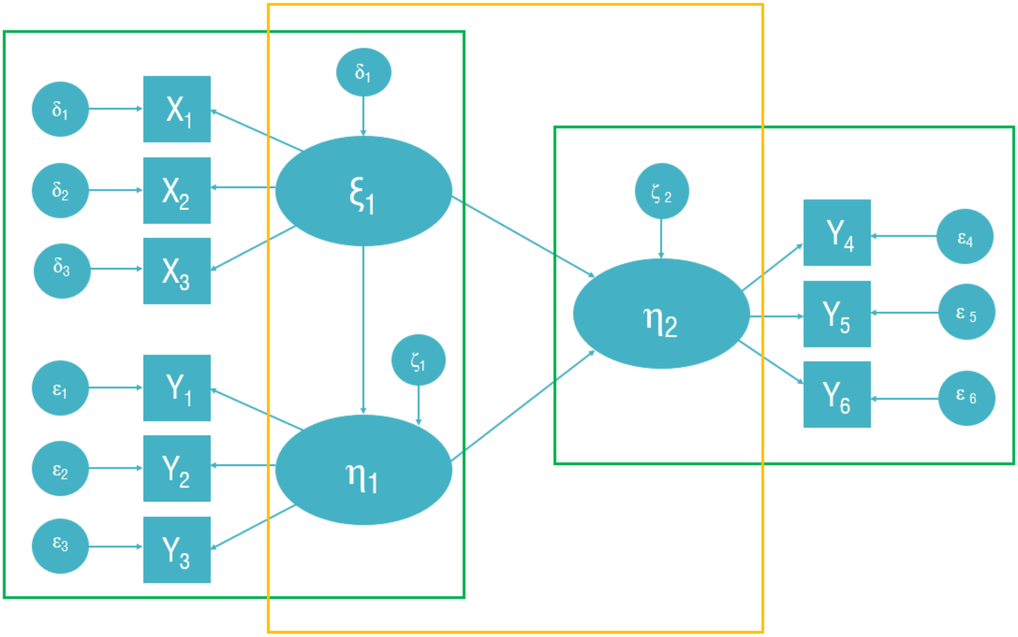


Figure 4.6 SEM model theory

In the structural model, the causal relationships among the latent variables are estimated. In compact notation, it takes the form represented in equation 1 in which the three vectors of endogenous (η), exogenous (ξ), and error (ζ) variables are present. Γ represents the matrix of path-coefficients between the endogenous and exogenous latent variables; B represents the matrix of path-coefficients between the endogenous latent variables. (LA Hayduk - 1987).

$$\eta = B\,\eta + \Gamma\,\xi + \zeta \text{ (Equation 1)}$$

The second base equation model takes the form represented in equation 2 in which there are the three vectors of observed endogenous variables (Y), latent endogenous variables (η), and errors (ε). (Λy) represents the coef. matrix of the measurement model for the observed endogenous variables (LA Hayduk - 1987).

$$Y = \Lambda y\,\eta + \varepsilon \text{ (Equation 2)}$$

The third basic equation takes the form represented in equation 3 in which there are the three vectors of observed exogenous variables (X), latent exogenous variables (ξ), and errors (δ). (Λx) represents the coef. matrix of the measurement model for the observed exogenous variables (LA Hayduk - 1987).

$$X = \Lambda x\,\xi + \delta \text{ (Equation 3)}$$

Among the various existing structural equation models, those based on covariance were used for the present study have the purpose of obtaining estimates of the free parameters of the model while preserving the information contained in the observed variance/covariance matrix. They can be regarded as a generalization of Confirmatory Factor Analysis dating back to Thurstone (1947). They rely on maximum likelihood (ML) to estimate the parameters of a model that involves causal links between latent variables in addition to measurement links.

SEM-ML has four distinct phases:

- the specification of the model;
- the identification of the parameters;
- the estimation of the parameters;
- the validation of the model;

The first phase responds to the desire to create a model that can structure the perception of risk, taking into account all the variables used in the literature. For this reason, a literature review was done.

Figure 4.7 summarizes the links between observed and latent variables used in the model. These relationships find support in the literature, as demonstrated in Table 4.4 (attachment).

The relationship between the latent variables is illustrated in Figure 4.8 and finds support in the literature from the work shown in Table 4.5.

Figure 4.7 Relationship between observed and latent variable

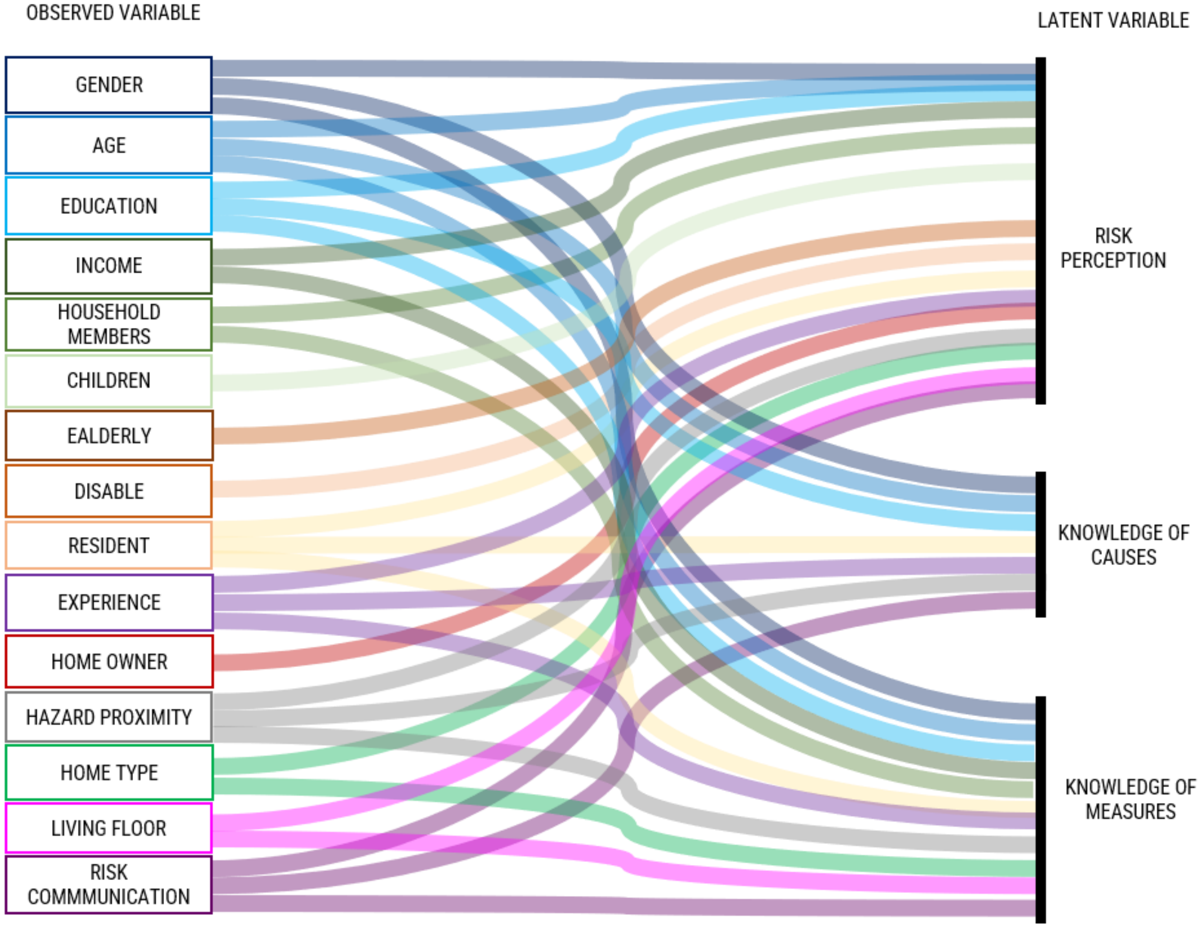


Figure 4.8 Relationship between latent variables

Table 4.5 Some indicative references regarding the relationship between latent variables

Relationship	Indicative references
R1	Siegrist & Cvetkovich, 2000; Tepstra et al. 2009; Siegrist, Gutscher, & Earle, 2005; Grothmann & Reusswig 2006
R2	Miceli et al., 2008; Kellens et al. 2013; O'Neill et al, 2016; Duzı´ et al. 2014;

Parameter estimation is done by looking at the p-value, and R^2.

The last phase regards the modifications of the model in the sense that if it comes defined as inappropriate to represent the data, it proceeds to the modification and the phase of the validation is repeated. This last one is based on the use of tests and indices like: the chi-square, the index of goodness of fit (GFI), and the adjusted GFI (AGFI):

$$GFI = 1 - \frac{Ti}{max\ Ti} \quad \text{(Equation 4)}$$

Where the value of the T-statistic is standardized with its maximum value. The GFI is between 0 and 1, and models with a value greater than 0.9 are considered good models:

$$AGFI = 1 - \frac{k}{df}\,(1 - GFI) \quad \text{(Equation 5)}$$

where df represents the degrees of freedom of the model and k the number of variances and covariances included in the model. Also, the AGFI is comprised between 0 and 1 and, like in the case of the GFI, they are considered good models if they introduce a greater value.

Another's parameters taken into consideration are the root mean square error of approximation (RMSE) with a value between 0 and 0,08 Chi-square ($\chi 2$) / Degree of freedom (df) with the value of ≤ 3.

4.2.4 HYBRID CHOICE MODEL BUILDING

To jointly account for both observed and latent variables, a Hybrid Choice Model has been proposed (BenAkiva, 1999). Hybrid models are composed of Latent Variable Models (LVMs) and Discrete Choice Models (Figure 4.9).

In this construct, as in random utility models, user choice is measured through utility (random variable). The utility is influenced beyond that from attributes directly observable (relative to the socio-demographic characteristics) also from relative psychological factors to the perception of the individuals.

The output of the Latent Variable Model is the measurement of latent attributes.

The results of the measurement of latent variables in the discrete choice model occurred through factor analysis and subsequently introduced within the utility (Prashker, 1979).

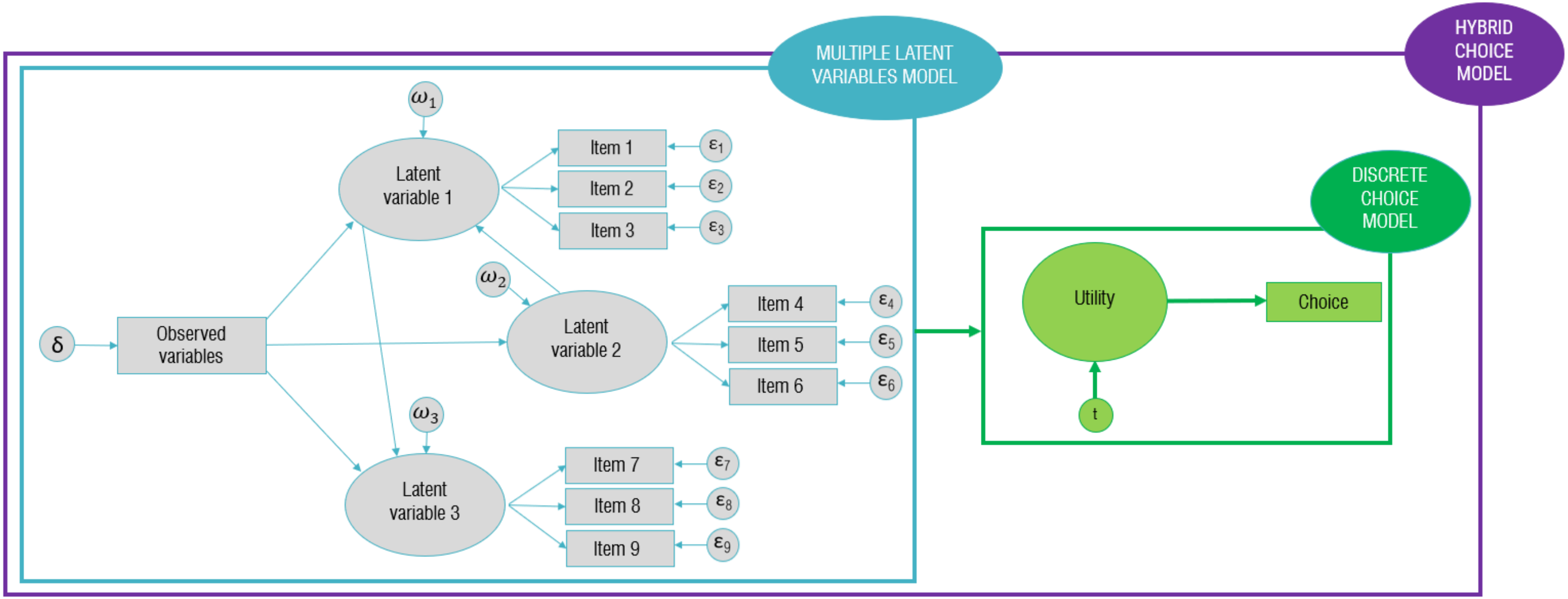
Two different equations (structural equation and measurement equation) are specified for the estimation of latent attributes. Through the structural equation (structural equation) it is possible to measure the relationship between the latent variables and the socio-demographic characteristics of the population, through the measurement equation (measurement equation) the relationship between behavior and perception is quantified.

$$RPh = bE \cdot Oh + bi \cdot L\,h + \omega,\ \omega \sim N\ (0, \sigma R)\ \text{(Equation 6)}$$

Equation 6 is the structural equation that links perceived risk (RPh) to observed variables (Oh) and latent factors (Lh). While RPh is a scalar quantity, Oh is a vector (1 X α) where α identifies the number of observed variables and Lh is a vector (1 X β) that identifies the β latent factors.

Consequently, bE and bi are the respective (1 X α) and (1 X β) vectors that define the weight of each observed and latent variable on risk perception. Finally, risk perception has an error component ω that is usually distributed with a mean equal to zero ana d standard deviation equal to σR. Similarly occurs with the other latent variables.

Figure 4.9 Hybrid Choice Model framework



Equation 7 is the structural equation that links perceived risk and the utility (Uh) required to move from one behavioral state to another behavioral state. ρ is a scalar quantity that defines the weight of perceived risk. Finally ,th utility has an error component τ that has a logistic distribution with a mean equal to zero and a standard deviation equal to 1.

$$Uh = \rho\ R_h + \tau,\ \tau \sim L\ (0,1)\ \text{(Equation 7)}$$

Equation 8 is the measurement equation that links perceived risk to Yh items. In this paper, these are measured using a Likert scale approach, as explained in methodology section 4.2.1. Yh corresponds to a (1 x γ) vector while br is a (1 x γ) vector that defines the weight of perceived risk where γ is the number of indicators that measure perceived risk. Finally, there is a (1 X γ) vector of normally distributed error components, ε, having a mean equal to zero a covariance matrix Ω.

$$Yh = brRh + \varepsilon,\ \varepsilon \sim N\ (0, \Omega)\ \text{(Equation 8)}$$

4.3 RESULTS AND DISCUSSION

4.3.1 SEM RESULTS

Before proceeding to the data analysis, the data collected by the E-survey were coded according to Table 4.6.

Subsequently, data analysis of the variables that influence the perception of flood risk is conducted to identify the factorial structure of citizens' flood risk perception.

Specifically, an Exploratory Factor Analysis (EFA) was adopted to reduce the number of variables that describe the perception of risk, while maintaining a good variability explained.

To identify the factorial structure of the scale, EFA postulates were tested: the Kaiser-Meyer-Olkin (KMO) and Bartlett's test of sphericity. The KMO and Bartlett test from which a value of 0.9 emerged, considered valid to proceed with the analysis.

Exploratory factor analysis (EFA) used maximum likelihood extraction and varimax rotation methods to estimate factor loadings.

Table 4.6 Variables code

Categories	**Description**	**Value in analysis**
Gender	Male;	0
	Female	1
Age	<18	1
	19-30;	2
	31-45	3
	46-60	4
	61-75	5
Education	Elementary license	1

	Middle school	2
	High school	3
	Bachelor's degree	4
	Master's degree	5
	PhD	6
Income (per year_euro)	< 7.500	1
	7.500-10.000	2
	10.000-15.000	3
	15.000-30.000	4
	30.000-50.000	5
	50.000-70.000	6
	>70.000	7
Household members	1	1
	2	2
	3	3
	4	4
	5	5
	≥6	6
Presence of children	Yes	1
	No	0
Presence of elderly	Yes	1
	No	0
Presence of disable	Yes	1
	No	0
Resident	Yes	1
	No	0
Direct experience	Yes	1

	No	0
Homeowner	Yes	1
	No	0
Hazard proximity	Yes	1
	No	0
Home type	Apartment building	1
	Isolated house	0
Living floor	Ground floor	1
	Beyond the first floor	0
Risk Communication	Yes	1
	No	0

Through AFE, it has been possible to identify the most suitable items to measure the different latent factors, going from the initial 22 items (Table4.2) to 9, shown in Table 4.7.

Table 4.7 The content of the E survey

Question theme	Question	Item	Code in the model
Risk Perception	Indicate how exposed you are to a flood (Likelihood) x Indicate the degree of damage due to the flood (Severity)	In your district	Item 1
		In your city	Item 2
		In your neighborhood	Item 3
Knowledge of measures	Indicate your level of knowledge about the	Mitigation measures	Item 4
		Protection measures	Item 5

		Post-event measures	Item 6
Knowledge of flood causes	Indicate, according to your knowledge, the extent to which the following activities contribute to increased flood risk	The lack of hydraulic defense measures	Item 10
		Building growth in constrained areas	Item 11
		Improper sizing of the sewer system	Item 12

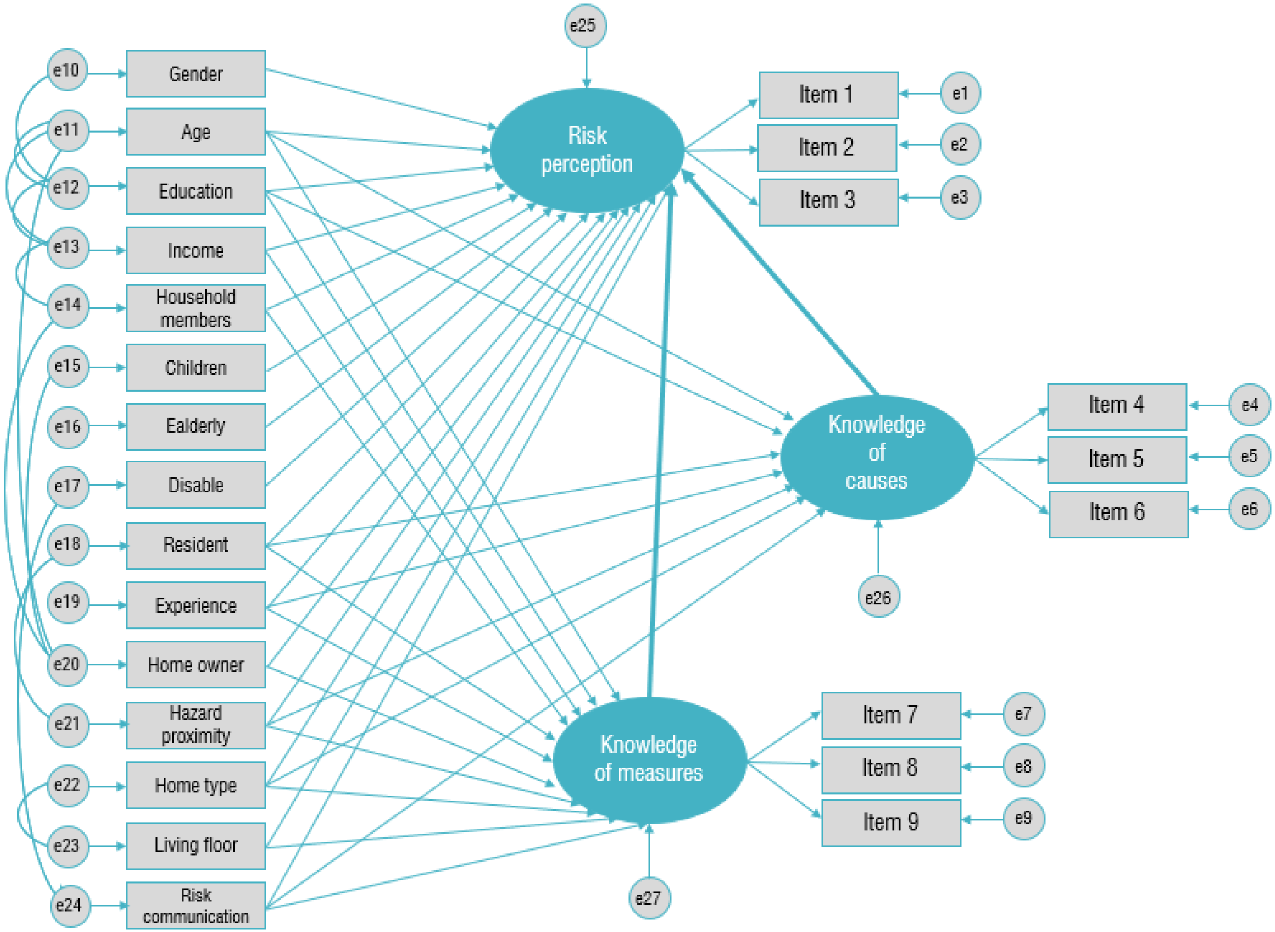
Saturations with a value less than 0.4 are considered insignificant and therefore were excluded from the modeling. The remaining values were reordered in descending order as shown in Table 4.8.

Table 4.8 Value from Factorial Analysis (% cumulative variance explained: 69, 174)

Item			
	1	2	3
1	0,939		
2	0,610		
3	0,572		
4		0,931	
5		0,718	
6		0,613	
7			0,999
8			0,666
9			0,568

The AFE results were analyzed with AMOS 26 to run the SEM model and test hypothetical relationships between constructs. The SEM is shown in Figure 4.10.

Figure 4.10 SEM model build on SPSS



The SEM model applies a theoretical framework, defined after a literature review, to the case study. It tests its validity under real-world conditions. The results of our model are in line with the model hypothesized from the relationships found in the literature.
Several indices of fit are examined to assess the fit of the path model: Chi-square ($\chi 2$) / Degree of freedom (df), the root mean square error of approximation (RMSEA), the goodness of fit index (GFI), and the adjusted goodness of fit index (AGFI).
The validity of the model is confirmed by reading the indices in Table 4.9.

Table 4.9 Model Fit

Sample size = 752
df =216
Chi-square = 2298,121
Probability level = ,000
GFI= 0, 899
AGFI = 0, 855
RMSEA = 0,074

The SEM model confirms the relationships between the latent variables through acceptable R^2 values. (Table4.10)

Table4.10 Squared multiple correlations

Risk perception	0,9
Knowledge of measures	0,5
Knowledge of causes	0,3

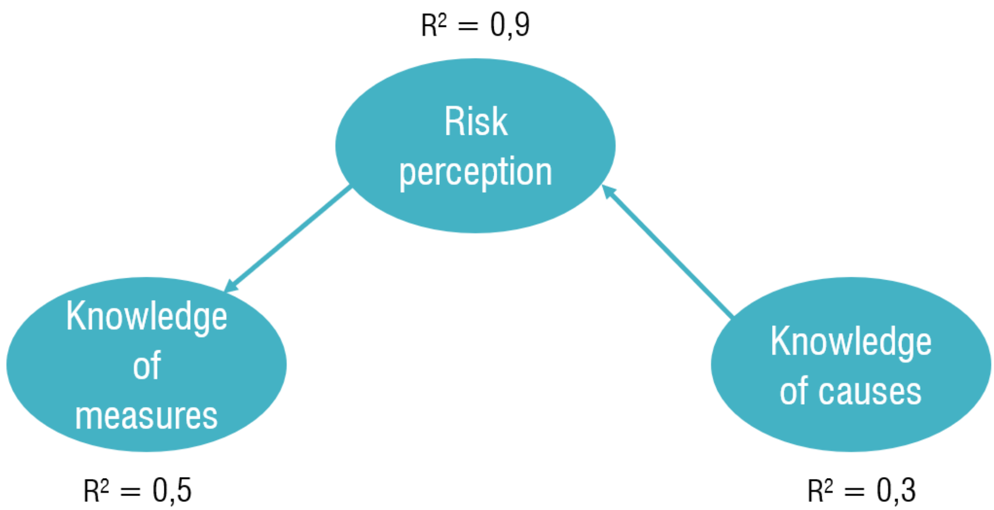


Figure 4.11 Relationship between latent variables and R^2 values

Looking at the values that emerged from the model, it is possible to see an acceptable value of R^2 except for the latent factor 'Knowledge of Causes'. It is not surprising when it comes to modeling complex phenomena where the variability is high and the background noise is given by several different elements. Moreover, as mentioned in the methodological section, latent variables are highly dependent on the study context.

This means that in all likelihood this variable used is not very explanatory of the perception of flood risk in the city of Bari, but it is not certain that it cannot be so in other contexts.

The SEM model also confirms the relationships between the observed and latent variables through statistically significant p-values (highlighted in bold in Table 4.11).

Table 4.11 Statistical significance in bold (*p value ≤0,05; **p value ≤0,1; ***p value ≤0,01)

			Estimate	P
KC	<---	GND	0,659	**0,000**
KC	<---	AGE	0,543	**0,000**
KC	<---	EDU	0,68	**0,000**
KC	<---	RES	0,764	**0,000**
KC	<---	EXP	0,604	**0,000**
KC	<---	RC	0,755	**0,000**
KC	<---	HP	0,074	0,483
KC	<---	HT	0,344	**0,018***
RP	<---	GND	0,057	**0,041***
RP	<---	AGE	-0,008	0,799
RP	<---	EDU	0,064	**0,027***
RP	<---	INC	-0,007	0,437
RP	<---	HM	-0,015	**0,067*****
RP	<---	CHI	0,069	**0,027***
RP	<---	EAL	-0,006	0,838
RP	<---	DIS	-0,067	**0,086****
RP	<---	RES	0,018	0,509
RP	<---	EXP	3,57	0,000
RP	<---	RC	0,055	0,201
RP	<---	LF	0,098	**0,075****
RP	<---	HO	-0,009	0,755
RP	<---	HP	0,018	0,515
RP	<---	HT	0,082	**0,076*****
RP	<---	KC	0,023	**0,026***
KM	<---	GND	0,28	0,000

KM	<---	AGE	0,955	0,000
KM	<---	EDU	-0,236	**0,008***
KM	<---	INC	-0,027	0,309
KM	<---	HM	0,353	0,000
KM	<---	RES	0,73	**0,000**
KM	<---	EXP	-6,22	**0,000**
KM	<---	RC	0,267	**0,038***
KM	<---	LF	0,109	0,523
KM	<---	HO	0,177	**0,039***
KM	<---	HP	0,388	**0,000**
KM	<---	HT	0,52	**0,000**
KM	<---	RP	1,753	**0,000**
RP1	<---	RP	1	**0,000**
RP2	<---	RP	0,824	**0,000**
RP3	<---	RP	0,805	**0,000**
KC1	<---	KC	1	**0,000**
KC2	<---	KC	0,974	**0,000**
KC3	<---	KC	0,716	**0,000**
KM1	<---	KM	1	**0,000**
KM2	<---	KM	0,968	**0,000**
KM3	<---	KM	0,919	**0,000**

Since almost all of the variables are statistically significant, it was analyzed which of them affects each latent factor the most.

Table 4.12 shows the regression weights for predicting the unobserved variables from the observed variables. It is organized with one row for each unobserved variable and one column for each observed variable.

Table 4.12 Regression weights for predicting the unobserved variables from the observed variable

	KC	RP	KM
HT	0,05	0,01	0,11
RC	0,11	0,01	0,06
HP	0,01	-0,01	0,08
EXP	-0,05	1,75	-0,65
RES	0,12	-0,03	0,14
EDU	0,10	0,04	-0,04
AGE	0,08	-0,05	0,18
GND	0,10	0,01	0,06
LF	-0,01	0,04	0,04
HO	0,00	-0,01	0,03
DIS	0,00	-0,03	-0,01
EAL	0,00	0,00	0,00
CHI	0,00	0,03	0,01
HM	0,00	-0,02	0,07
INC	0,00	0,00	-0,01
KM3	0,00	0,01	0,17
KM2	0,00	0,03	0,41
KM1	0,00	0,02	0,26
KC3	0,16	0,00	0,00
KC2	0,33	0,00	0,00
KC1	0,41	0,00	0,00
RP3	0,01	0,18	0,07
RP2	0,02	0,26	0,09
RP1	0,01	0,15	0,06

The data are represented by the Pareto diagram (Figures 4.12, 4.13, and 4.14).
As can be seen from Figure 4.12, the variable ‘experience’ has an impact of more than 90% on perceived risk.

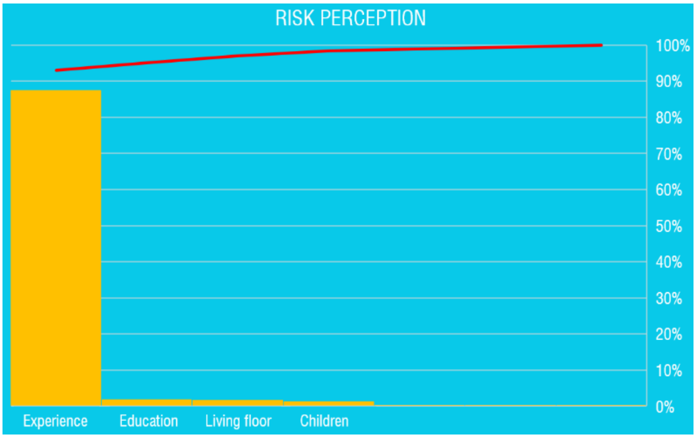


Figure 4.12 The impact of the observed variables on *Risk perception*

Being a resident and communicating about risk have an impact of more than 80% on knowledge of causes (Figure 4.13). Affecting knowledge of the measures is age and residency (Figure 4.14).

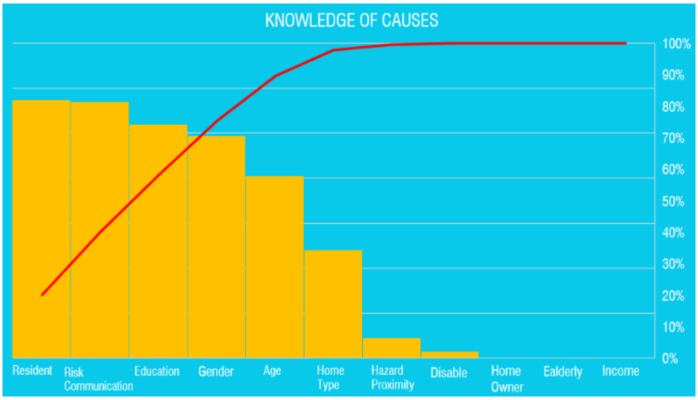


Figure 4.13 The impact of the observed variables on *Knowledge of causes*

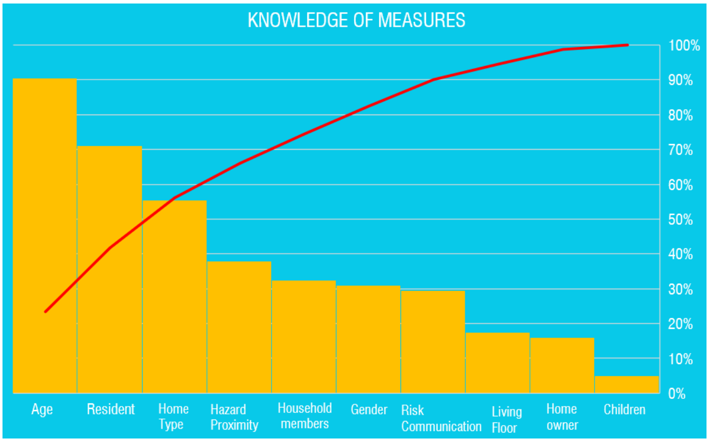


Figure 4.14 The impact of the observed variables on *Knowledge of measures*

Looking at Fig. 4.12, it is possible to see a strong preponderance of the experience variable on risk perception, compared to the other variables.

The literature review reveals that people can have very different backgrounds regarding their experience with floods, and these differences influence how they perceive risk and act to reduce it (Bubeck et al., 2012; Ho et al., 2008; Grothmann et al., 2006; De Koning et al., 2019).

Experience can be of two types: direct and indirect (Weinstein 1989; Botzen et al., 2009; Mondino et al., 2020). People with direct flood experience tend to perceive the risk/threat or its potential consequences as more severe because they use more flood information resources, or experience particular emotional responses to floods (Weinstein 1989; Siegrist et al., 2008; Burningham et al., 2008; Botzen et al., 2009; Kellens et al., 2013; Wachinger et al., 2013; Wang, Z., 2018).

In this study, participants were asked if they had any direct experience with the event. The number of sample respondents was far fewer than the total number of citizens involved, as seen in Fig. 4.15.

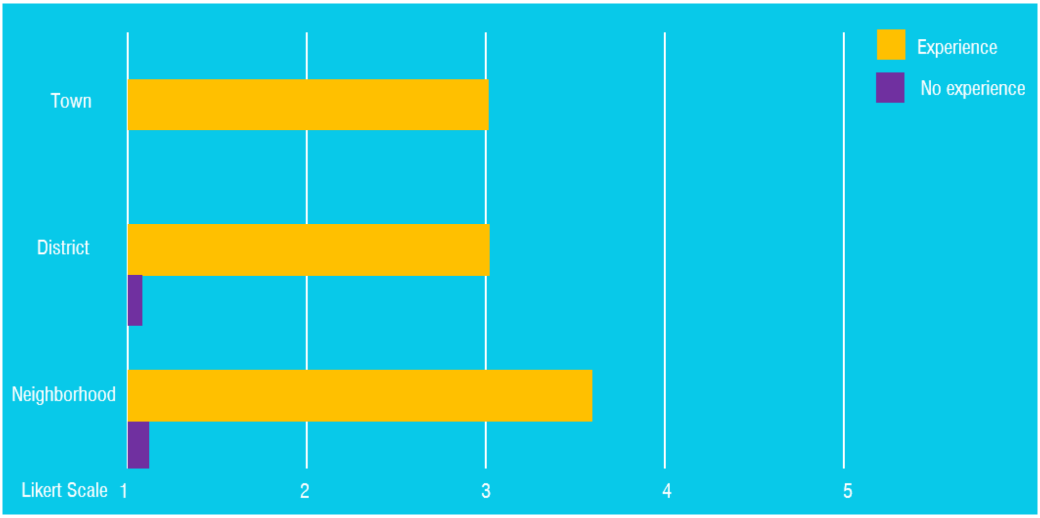


Figure 4.15 Degree of flood risk perception relating to *direct experience* variable

Consistent with what is reported in Table 4.3, those who have had a direct experience represent only 19.44% of the total population.

On a Likert scale from 1 to 5, those who have had direct experience with the flood perceive the phenomenon with values between 3 and 4 in the district, while the perception value on a district and city scale is equal to 3.

The results demonstrate what has been reported in the literature in reference to a low perception of those who have not lived the direct experience. In fact, their perception assumes values very close to 1 on both territorial scales.

Another important aspect that the literature emphasizes, directly related to experience and affecting the way citizens perceive risk, is the temporal distance since the last event. While recently experienced floods may cause people to rate the likelihood and severity of a flood higher (Bamberg et al., 2017), i.e., risk perception, experiences from the more distant past seem to have rather less influence on risk perception.

The temporal variable was not included in the SEM model because from a review of the literature, the role of memory would need the insights and studies beyond the scope of engineering expertise. And in order not to induce in the error of the mere simplification of an extremely complex concept, an isolated question was asked concerning the memory of the last event, which would respond in a simple and effective way to our objective. Nothing excludes the possibility, that in the future, this component may be considered through expert contribution.

Consistent with the previously reported result regarding experience, most citizens have no memory of a flood event, 53.71%. Of those who do have memory of it, 26, 65% recall it happening within the last 5 years and 19.44%, more than 5 years ago. The latter percentage corresponds with those who have experienced it (Figure 4.16).

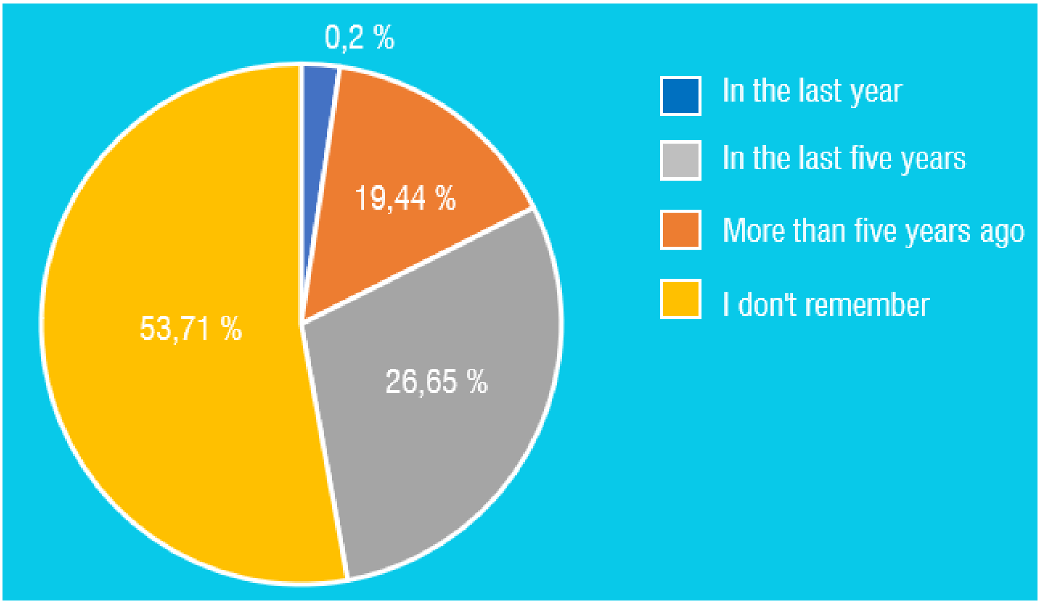


Figure 4.16 Memory of a flood event in the city of Bari. Percentage of respondent

From a risk management perspective, "the evanescent nature of disaster experience" (Wachinger et al., 2013) can lead to a false sense of security, decreased risk awareness, and the promotion of optimistic bias (Burningham et al., 2008). To summarize, the debate on the importance of magnitude and temporal aspect of flooding in relation to experience and relevant behavior is still ongoing (Aguilar-Barajas et al., 2019).

While on perception the main impact is given by the experience variable, on knowledge, more variables come into action.

From the observation of Fig. 4.13, it can be seen that more than 80% of the population that claims to know the causes of a phenomenon is resident, has acquired information through communication campaigns and has an educational level that exceeds a high school diploma. People with more education can have better knowledge about floods (Lave et al., 1991) clearer understanding of related terms and facts (Botzen et al., 2009), and tend to expect less government assistance and to endorse payments for property-level flood protection (Henstra et al., 2019).

Proximity with respect to the source of risk involves just under 10% of the population. Considering that most residents do not live in areas close to the risk, the result is consistent. In any case, it is not a result to be underestimated, given the different nature of floods (see Brindisi case study).

In relation to knowledge of the measures, Figure 4.14 shows that those who are older than 45, are residents, and live in an isolated home possess more knowledge.

4.3.2 HCM RESULTS

This section has been divided into three sub-sections, each containing results and suggestions to improve flood management.

Specifically, the results derived from the discrete choice model were ordered to define:

- the behavior for each flood risk scenario, to suggest elements to the decision-makers to address the planning in a more timely and effective way;
- For each risk scenario, the influence of perception and knowledge on protective behavior;
- for each risk scenario, the influence of observed variables on protective behavior.

4.3.2.1 SCENARIO RESULTS

From the results obtained from the SEM model, i.e., from the links defined between the observed variables and the latent variables as explained in Sect. 4.2.4, the actions were calculated through the HCM model.

To make the data more readable, the result obtained from the HCM was summarized in the following graph (Figure 4.17). The indicator is given by the ratio of those whose response falls into the protective behavior group to the total number of respondents. It indicates the attitude of citizens to adopt protective behaviors. The closer the value is to 1, the more the attitude falls into the protective action type. The indicator takes into consideration the totality of the aggregate population, without distinctions between categories.

As is evident from Figure 4.16, attitudes in three out of four scenarios are quite positive. In the specific, scenario 3 represents the situation in which citizens would take protective action. Scenario 1, on the other hand, presents less than encouraging results in terms of protective behavior.

These results could be understood in two ways:
- most individuals driving their cars are not likely to engage in protective behavior;
- the scenario does not take into account other variables, in addition to those considered in this study, that come into play and could influence behavior, i.e., the scenarios do not contain sufficient variables to explain behavior.
Several studies, analyze the variation in a citizen's perceived risk and their driving behavior of adverse weather conditions. Most of them develop indicators and models based on Wilde's homeostasis theory of risk (Wilde, 1982) where risk is a product of consequences and perceived probability.
In the work of Hjelkrem et al 2016, the Chosen Risk Index (CRI) is used which takes into account the time variable, speed, and vehicle weight. The results show that the perceived risk of car drivers tends to increase as weather conditions worsen. Under extremely poor visibility conditions, such as very dense fog, the measured drivers' perceived risk is high due to vehicle operation difficulties and limited visibility, different is the attitude for truck drivers.
The work of Chen et al.2019 considers other factors such as weather conditions and road type. These factors have a significant impact on driving behavior. Low-intensity fog and rain have a minor influence on drivers' perceived risk, while snow has a significant effect on perceived risk.
For the above reasons, the actual behavior may deviate from reality. It would be necessary to structure the methodology by implementing additional variables. In any case, since studies confirm an increase in perceived risk under adverse weather conditions and also an increase in accident rates (Hjelkrem et al 2016), it is still possible to suggest some insights for planning.
For example, enhanced signage on streets most at risk of flooding; digital signage in common gathering places showing measures to take in case of flooding while driving.

Several cities are equipped with digital systems, such as the islands of Greece for Tsunami warnings (Papadopulos et al.2020) or raising awareness of the subject starting in driving school, considering that young people, least of all, perceive and know about the measures.

The outcome of behaviors in the other scenarios find foundation in Prospect Theory (D. Kahneman & A. Tversky (1979).

Prospect Theory, proposed by the authors, describes decision-making processes composed of two stages (1) assembly, i.e., information gathering and analysis of different perspectives, and (2) evaluation of different possible scenarios and choice of the one that represents the subject the alternative with the greatest value.

Subjective choices are therefore derived from operations of simplification, cancellation, and consideration of the influence of context: the same person may make different choices when faced with the same problem precisely because of the presence of a process at the base that is unscientific and difficult to repeat.

Specifically, this theory is based on two assumptions:

(i) Context effect: the context in which the individual makes the choice, has a determining effect on the choice itself. In particular, how the problem is formulated affects how the individual perceives the starting point, against which to evaluate the possible outcomes of their actions.

(ii) Loss aversion: for most individuals, the motivation to avoid a loss is greater than the motivation to make it again. This general psychological principle, which is probably linked to a sort of survival instinct, means that the same decision can give rise to opposite choices if the outcomes are represented to the subject as losses rather than as lost earnings.

This mechanism seems to be more pronounced in scenario 3, where physical safety seems to play a greater role than the loss of a car.

In scenarios 2 and 4, this difference is less pronounced. The result is rather predictable. While in scenarios 1 and 3 the choice is made by the individual, the circumstances in scenarios 2 and 4 could change due to interaction with other individuals, thus triggering what is called the "herd effect".

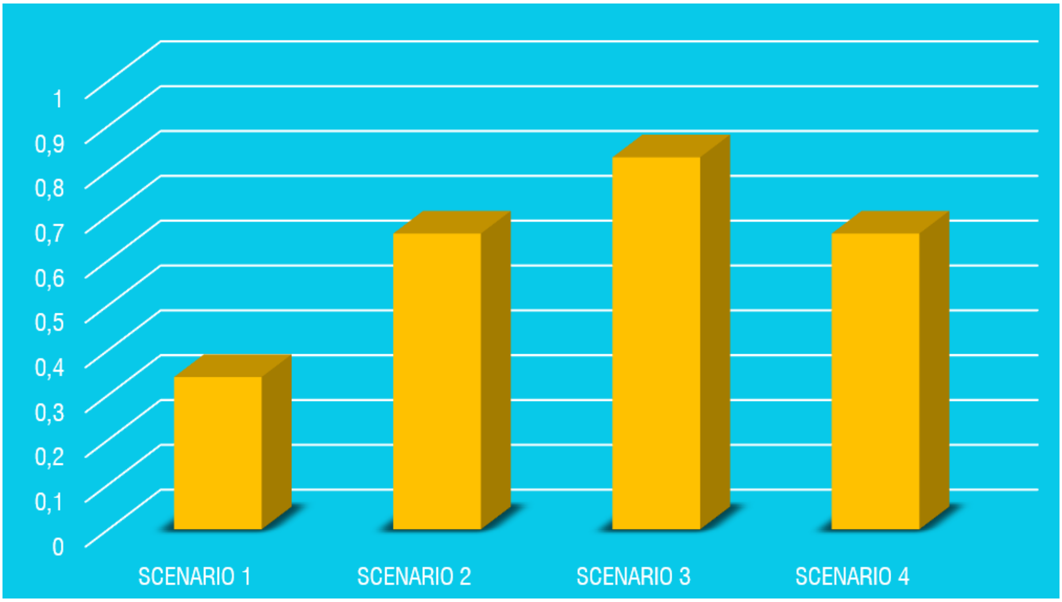


Figure 4.17 Citizens' attitudes toward protective behavior

4.3.2.2 LATENT VARIABLES INFLUENCE PROTECTIVE BEHAVIOR

Looking at scenarios 1 and 3, scenarios in which there is less protective behavior and protective behavior, respectively, the results reported in Table 4.13 show that latent variables do not affect behavior. These results are consistent with what was highlighted in the previous section, i.e., on the one hand, they do not present explanatory variables for each individual's behavior, and on the other hand, individuals' behavior could be imputed to the context effect. In scenario two, in which individuals are involved in a risky situation on foot, knowledge of the causes of the phenomenon and the measures seem to drive protective behavior (Figure 4.18). In scenario four, knowledge of measures seems critical to adopt protective behavior at home as well as risk perception (Figure 4.21).

Table 4.13 Statistically significance of latent variable

Latent variable	B	p value
SCENARIO 1		
Knowledge of causes	-0,067	0,47
Risk Perception	0,245	0,481
Knowledge of measures	0,045	0,656
SCENARIO 2		
Knowledge of causes	0,329	**0,002**
Risk Perception	0,245	0,601
Knowledge of measures	0,284	**0,015**
SCENARIO 3		
Knowledge of causes	-0,042	0,763
Risk Perception	-0,396	0,488
Knowledge of measures	0,148	0,317
SCENARIO 4		
Knowledge of causes	-0,201	0,074
Risk Perception	1,329	**0,001**
Knowledge of measures	0,363	**0,002**

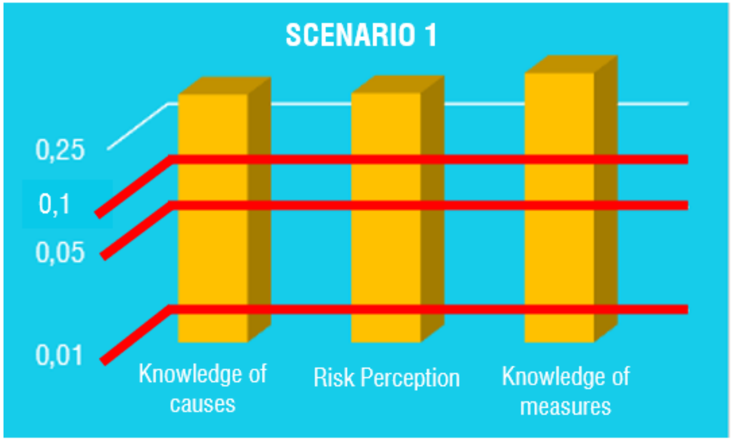


Figure 4.18 Statistically significance of latent variable_
Flood risk Scenario 1

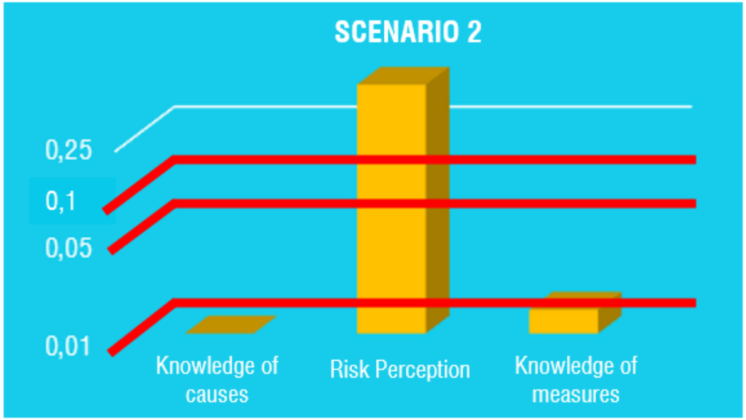


Figure 4.19 Statistically significance of latent variable_
Flood risk Scenario 2

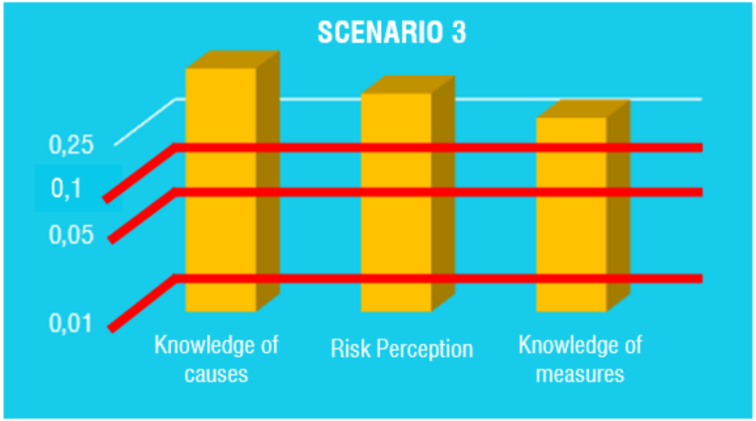


Figure 4.20 Statistically significance of latent variable_
Flood risk Scenario 3

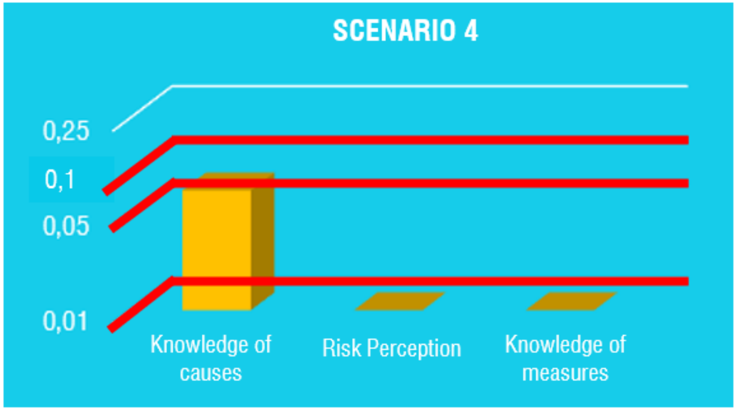


Figure 4.21 Statistically significance of latent variable_
Flood risk Scenario 4

4.3.2.3 OBSERVED VARIABLES INFLUENCE PROTECTIVE BEHAVIOR

Like the previous section, in this section, the analysis was done taking into account the influence of the observed variables on protective behavior. Tables 4.13 to 4.16 show the values of statistical significance.

About scenario 1, the statistically significant variables are N.members in the household (HM), Elderly (EAL), and Disabled (DIS). Looking at the B values, about the HM variable, it emerges that those who live in a family with less than 4 persons are less likely to have protective behavior. This result could be linked to a lack of communication within the family nucleus (Lackova et al.,2020).

About scenario 2, the statistically significant variables are Education (EDU), Presence of Elders (EAL), Risk Communication (RC), and Income (INC). Looking at the B values, attention should be paid to those who have an education lower than a diploma, those who have a low income, and those who have never been involved in a risk communication campaign. These results can be attributed to a lack of knowledge about the effects of the phenomenon, as confirmed in the literature by ref Kellens et al. 2013.

About scenario 3, the statistically significant variables are gender (GND), income (INC), disability (DIS), hazard proximity (HP), and home type (HT). Looking at the values of B, attention should be paid to those who live in isolated homes. They are less likely to have protective behavior. This behavior can be traced back to the sense of familiarity with the place where one lives (Botzen et al.2020).

About scenario 4, the statistically significant variables are gender (GND), age (AGE), elderly (EAL), experience (EXP), the homeowner (HO), hazard proximity (HP), home type (HT). Looking at the B values, the focus is on the men and youth category. Not surprisingly, men and youth tend to behave in a non-protective manner in this scenario.

Compared to women, these two categories tend to experience the homeless and therefore perceive risk differently and behave less conservatively.
As noted in the previous sections, the scenario analysis should be further explored because it does not consider other variables that could influence perceived behavior.
These results give some general indications to the decision-maker to support flood management, but they do not provide an exhaustive answer to actual behavior in risky circumstances.
After all, this work leverages the importance of adopting a bottom-up methodology but has several limitations. Among the others highlighted, the case study is not insignificant. From the application of the methodology on Bari, it can be inferred that in general the level of perception is on average low and is mainly linked to those who have had previous experience. But looking at the data, those who have had previous experience are far fewer in number than those who have not. This is no small point. The replicability of the model would allow it to be dropped on a different case study and obtain decidedly more significant results.
Attention should also be paid to another issue closely related to experience, which is that of memory. Only those who have had the experience can perceive the risk and its effects.
This element could provide decision-makers with the importance of communication and dissemination to increase the level of shared knowledge.

Table 4.14 Statistically significance Flood risk Scenario 1

Variables	B	Sign.
GND	-,200	,229
AGE	,028	,819
EDU	-,084	,350
INC	,059	,305
HM	**-,108**	**,094**
CHI	-,002	,994
EAL	**,308**	**,103**
DIS	**,760**	**,001**
RES	,046	,785
EXP	-,679	,589
HO	-,466	,521
HP	-,106	,530
HT	-,102	,714
LF	-,245	,454
RC	-,195	,447

Table 4.15 Statistically significance Flood risk Scenario 2

Variables	B	Sign.
GND	-,100	,612
AGE	,130	,381
EDU	**-,259**	**,016**
INC	**-,110**	**,093**
HM	,120	,124
CHI	-,263	,270
EAL	**,498**	**,036**
DIS	-,078	,781
RES	-,318	,119
EXP	-,292	,859
HO	-,007	,972
HP	-,206	,294
HT	-,439	,167
LF	,044	,903
RC	**-,753**	**,008**

Table 4.16 Statistically significance Flood risk Scenario 3

Variables	**B**	**Sign.**
GND	,807	**,002**
AGE	-,224	,211
EDU	-,164	,198
INC	,245	**,015**
HM	,164	,076
CHI	-,315	,312
EAL	,201	,467
DIS	1,015	**,028**
RES	,396	,116
EXP	2,265	,280
HO	,062	,807
HP	,829	**,002**
HT	**-,949**	**,006**
LF	-,289	,459
RC	-,550	,117

Table 4.17 Statistically significance Flood risk Scenario 4

Variables	B	Sign.
GND	**-,499**	**,009**
AGE	-,434	**,002**
EDU	-,004	,973
INC	-,105	,125
HM	,057	,445
CHI	-,081	,731
EAL	**,551**	**,021**
DIS	,329	,285
RES	-,172	,389
EXP	**5,095**	**,001**
HO	**,589**	**,003**
HP	,366	,067
HT	**-,608**	**,049**
LF	-,477	,172
RC	,052	,864
KM	,363	**,002**

4.3.3 Results summary: some suggestions to support flood management decision-making process and the implication for urban planning

From the results of the HCM have been found some suggestions to support the flood management decision-making process and the implication for urban planning, summarized in Table 4.18.

Table 4.18 Some suggestions to support flood management decision-making process and the implication for urban planning

Model	Factor	Relevant results	Citizens' cathegories to be involved	Suggestion to support flood management	Implication for urban planning
SEM	1. Risk perception	1.1 People with direct experience perceive more flood risk	1.1.1 Citizens under 45 years of age	Through a participatory process, elaborate a shared vision reflecting the concerns of the emerging category of citizens in order to provide ideas for collective mitigation actions	Non structural measures: Building horizontal links with different categories of citizens and vertical links between local and national government
		1.2 People with direct experience remember the largest event occurring more than five years ago			

		1.3 Age range of population reporting experience is between 46-60			
	2. Knowledge of causes	2.1 Residents and people with education levels above high school graduation report knowledge of the causes of the phenomenon in the city	2.1.1 Commuters and people with less than a high school education	To initiate a public awareness campaign in order to reach emerging categories. Example of communication via media, radio or television	Non structural measures: development of a road plan in emergency conditions
					Structural measures: Install dedicated road signs and mobile barriers
					Structural measures: Maintenance/redesign of flood-prone areas/affected infrastructure to ensure proper water run-off

	3. Knowledge of measures	3.1 The 46-60 age group and to a small extent the 30-45 age group, residents, people who live in an isolated house, and people living in at-risk areas	3.1.1 Citizens under 30 years of age, commuters, people living in buildings at street floor and people not living in hazard proximity (considering the multiple nature of flooding and for this study the hazard proximity has been assessed only according to PAI)	To initiate a public awareness campaign in order to reach emerging categories. Example of communication through social media (involving young people); school seminars (involving young people up to 20 years old); institutional websites (for other categories of citizens)	Non structural measures: Building horizontal links with different categories of citizens and vertical links between local and national government
HCM	4. Flood risk scenario 1	4.1 This scenario reports less than encouraging results in terms of propensity for protective behavior	4.1.1 People who drive an automobile and people who live in a household of less than four people	To initiate a public awareness campaign in order to reach emerging categories. Example of communication via media, radio or television	

	5. Flood risk scenario 2	5.1 Knowledge of measures and causes increases attitude toward protective behavior	5.1.1 see categories of citizens involved in 2.1.1 and in addition attention should be paid to people with less than a high school, people with low income and those who have never been involved in a risk communication campaign.	To initiate a public awareness campaign in order to reach emerging categories. Example communication through events in public spaces (squares, hubs, gathering places within neighborhoods)	Structural measures: renovation and/or creation of public gathering spaces
	6. Flood risk scenario 3	6.1 People living in isolated houses show lower protective behavior attitudes	6.1.1 Care should be taken for those living in isolated houses	To initiate a public awareness campaign in order to reach emerging categories. Example targeted communication through institutional guidelines mailed in territorial areas	Non structural measures: Building horizontal links with different categories of citizens and vertical links between local and national government

				characterized by extensive housing	
	7. Flood risk scenario 4	7. Knowledge of measures and causes increases attitude toward protective behavior	7.1.1 see categories of citizens involved in point 3.1.1 and in addition the focus is on the men and youth category	To initiate a public awareness campaign in order to reach emerging categories. Example of communication through social media (involving young people); school seminars (involving young people up to 20 years old); institutional websites (for other categories of citizens)	

5.0 GENERAL CONCLUSION

This study provides a preliminary assessment and structuring of citizens' perceptions and knowledge of flood risk, in order to evaluate citizens' attitude to protective behavior and provide useful elements to support planning decision-making for flood management. Finally, although not among the main objectives of the work, it tried to identify some implications for urban planning relating to the results emerged. Some results highlight the importance to integrate urban planning and flood management, as widely discussed in Chapters 1 and 4.3.3.

The proposed methodology comes from a path developed in different times and experimentally applied to two case studies: Brindisi and Bari.

In this path the research questions have grown, increased and become more and more complex with the consequent search of possible ways.

The first research question to which an answer has been sought is whether there are elements that influence citizens' perception and knowledge of flood risk in urban areas. In order to answer this question, a literature review was carried out that allowed the construction of a theoretical model on the basis of which the E Survey to be submitted to the population of Brindisi and then to the case study of Bari.

In the case study of Brindisi, the data collected and processed through statistical tools such as Mann-Whitney and Kruskal-Wallis test, allowed to understand how citizens living in areas exposed to hydrogeological risk perceive flood risk and to what extent they know the protective measures to deal adaptively with a future flood event. The results show that the perception of flood risk is strongly related to variables such as trust in institutions, institutional communication and information. This is reflected even more in the categories of under 18 years of age and below. Previous experience, in

relation to perceived flood risk, plays a role in the awarness dimension alone while in relation to knowledge of protective measures, it is slightly higher for those who have experienced the event. In addition, a slightly higher perception emerged for those who live in areas at risk, but the results of the rest show that there is a non-negligible perception even where there is apparently no source of risk. This is reflected in the diverse nature of the flooding that has affected the city and should serve as input for policymakers to conduct investigations into latent risks. The findings provided insights into the specific case study and allowed for the development of suggestions for possible measures to be adopted or implemented in planning tools (see Table 3.8).
This work adds to the numerous studies of structuring risk perception and knowledge aimed at supporting flood risk management processes. Although the methodology provided interesting outputs in terms of research, it failed to highlight other aspects.
For example, the prevailing elements of risk perception and the correlation between perception and knowledge and the consequent actions that citizens might take under conditions of risk.
These two uninvestigated aspects opened up two other research questions, which found an experimental application in the Bari case study.

Through factor analysis, it was possible to highlight the existence of a structure of latent factors, representing the prevailing elements of flood risk perception, which were then used in the construction of the SEM model.
The implementation of the SEM model to a utility model, the DCM, made it possible to structure risk perception and knowledge, correlate it and define the attitude to protective behavior in different risk scenarios.
The attitude to protective behavior was defined inspired by the Protection Motivation Theory, by Grothmann and Reuwiss (2006). Specifically, it follows the strand of

innovation introduced by Babcicky and Seebauer (2019), who extended PMT with the statistical technique of Structural Equation Modeling (SEM).
The creation of the model of this work fits into this context of innovation by partially inspiring and incorporating the utility model for the creation of an HCM.
The use of this type of hybrid models in the field of flood management is still poorly investigated, but looking at the fields of economic modeling, transportation and evacuation they are very effective, as amply demonstrated in Chapter 1.
In this still under-investigated field, it is believed that the adoption of models of this type but even more, the structuring of the presented methodology can add value to the current scientific and technical debate.
In fact, in the field of flood management, among others, there are difficulties related to:
(i) collection of information related to the social sphere (Voinov et al., 2016);
(ii) structuring the components related to the social sphere (Rundmo et al., 2017; Leckowska 2018; Santoro et al., 2019);
(iii) to the modeling of human characteristics (Jonkman and Dawson 2012), such as perception, knowledge, behaviors (Rundmo et al., 2017; Leckowska 2018; Santoro et al., 2019); .
Which are addressed in the present study as follows:

- Referring to the techniques of collecting and managing information through an online semi-structured interview, which has the advantage for the analyst to create a database to be checked and analyzed in a short time, information to be spatially localized and data to be used for more accurate analysis. Elements that would improve the flood risk management process by planning more precise strategies focused on specific categories of citizens based on their demographics and location in an urban area at risk.

The use of this approach certainly has limitations: one intrinsic, related to the type of approach used; the others, related to the boundary conditions related to the period of health emergency during which the thesis was carried out.
In fact, the type of questions set on a Likert scale provides results in an aggregate form of the knowledge and perception of citizens, neglecting any facets, known for example from open-ended questions. Even in this case, however, problems would arise related to the interpretation and analysis of textual data.
In addition, it might have been interesting to include the perception and knowledge of citizens who do not use the web platform and to disseminate the questionnaire in a targeted manner in different geographical areas.

- In relation to the structuring of the components related to the social sphere, in this study risk perception and knowledge declinations were structured. In the literature, these components are addressed according to many approaches. From statistical modeling (Miceli et al., 2008) to the use of soft methods such as Fuzzy Cognitive Maps (Santoro et al., 2019). In the present study, an SEM model was chosen to be used.

On the other hand, although created based on a search for the most widely used elements in the literature, it provides a basis for a larger model that could be implemented with additional variables. This element represents the added value related to the replicability and ability to implement the model.

- In relation to the modeling of human characteristics, advances in social simulation techniques are making it possible to explore the responses of citizens under conditions of risk. Rijcken et al. show how serious gaming can be used as an interactive tool, including for recording stakeholder preferences. Elsewhere, Dawson et al. 2011, applied agent-based modeling techniques to simulate the evacuation of a flood-prone city.

The role of social science and public participation in understanding human behavior remains crucial.

These existing models, and those that emerged from this work, could certainly be improved by incorporating social science input; however, early results show great potential for substantially advancing our understanding of the role of people and communities in flood risk management.

In fact, looking at the results from both case studies, it is possible to see that both structural and non-structural planning measures have been proposed, to the benefit of what was discussed in Chapter 1.

In relation to the Brindisi case study, the results were organized to define temporally and spatially placed measures and suggestions.

Identifying the variables that influence community heterogeneity can be useful for policy makers, disaster managers, and various professionals who must coordinate and communicate with different levels of government, classes of action, and at various points in the disaster management cycle.

The case study of Bari, even less so than Brindisi, certainly did not help in formulating suggestions for land use planning. It has emerged how distant is the memory of citizens and consequently also the perception of risk.

In spite of this, it has been possible to deduce that, there are not places more than others, that could represent a potential danger for the citizens because the proximity to the source of risk has not resulted a variable that produces implications on the perception; the knowledge of the causes of the phenomenon is possessed more from the residents and from those who or have assisted to information campaigns or that have a higher level of education. And knowledge of the causes of the phenomenon implies an increase in perception of the risk; residents also possess knowledge about the measures to be taken along with those who are over 45 years old (and who have

probably experienced the event) and those who live in isolated houses. This is likely because they have been called upon to take action on their own.
Some suggestions to support the planning process would be to initiate an integrated citizenry/institutional knowledge process that includes non-residents and commuters. This could be achieved through training and outreach within workplaces. Reach out to younger age groups. This is possible not only through targeted social campaigns but also through cycles of meetings in schools or in the places most frequented.
Although perception was low, it was possible to infer some suggestions for land use planning. The creation of an HCM in a place where one has more experience with the event, or a city that develops around a river, would surely give more relevant results and provide more detailed indications to support flood risk management (see table 4.18).
In conclusion, the methodological approach adopted in this study allowed to:
- To structure, elicit and validate two purely qualitative concepts: perception and knowledge;
- To assess how these two dimensions affect a citizen's ability to take protective action, in specific risk scenarios. And therefore to create a connection between perception and action.
- To know the categories of citizens most exposed in order to act with timely and effective strategies.
- To suggest some suggestions of integration between territorial planning and flood management
This work represents only the beginning of a path for the construction of agent-based models that could be developed in many ways, from the implementation of equations to support artificial intelligence, to the construction of simulation spaces in virtual reality.

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Stefania Santoro

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Ingegnere dei Sistemi Edilizi, nata a Bari il 26/12/1987

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Principali esperienze professionali

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(01/09/2018 31/10/2019)	Sviluppo e applicazione di metodi per la riduzione dei rischi legati alle acque Attività relative al progetto di ricerca europeo NAIAD (Nature Insurance value: assessment and demostration) sul ruolo della natura come strumento di mitigazione delrischio legato alle acque. Responsabile scientifico: Ing. Raffaele Giordano
(26/06/2017 25/06/2018)	Sviluppo e applicazione di metodi per la riduzione dei rischi legati alle acque Attività relative al progetto di ricerca europeo EDUCEN (European Disaster in Urban Center) sul ruolo degli aspetti culturali di una società in una situazione di rischio idraulicoin ambito urbano. Responsabile scientifico: Ing. Raffaele Giordano

Attività didattica

AA 2020/2021	Politecnico di Bari, via Orabona 4, 70126, Bari. Dipartimento di Ingegneria Civile, Ambientale, del Territorio, Edile e di Chimica,DICATECh, 080 596 3564 Incarico di sostegno alla didattica per l'insegnamento del corso di Ingegneria del territorio. Corso di laurea magistrale Ingegneria civile LM23. Responsabile scientifico: Domenico Camarda, ordinario Ingegneria del Territorio
AA 2020/2021	Comune di Brindisi, Piazza Matteotti, 1, 72100, 0831 229111 Attività didattica nel ciclo di Seminari_ Sustainability seminars "NBS (Nature-basedsolutions) per incrementare la resilienza urbana". Responsabile: Livia J.Dell'Anna. Consigliere Comune di Brindisi.

Analista di processi partecipativi di piano

Novembre 2018
Febbraio 2019

Comune di Brindisi, ripartizione Pianificazione e Gestione del territorio, via Casimiro 36; Brindisi
Organizzazione del processo di partecipazione pubblico finalizzato alla redazione del Piano Urbanistico Generale del Comune di Brindisi;
Redazione documento di sintesi.
Responsabili: Arch. Marina Carrozzo, dirigente ufficio Pianificazione e Gestione del territorio; Ing. Dino Borri, Assessore all'Urbanistica

Editore rivista scientifica

2019 ad oggi

Politecnico di Bari, via Orabona 4, 70126, Bari Dipartimento di Ingegneria Civile, Ambientale, del Territorio, Edile e di Chimica, DICATECh

Rivista di pianificazione territoriale Plurimondi,
http://plurimondi.poliba.it/index.php/Plurimondi

Istruzione e formazione

Laurea Magistrale

Politecnico di Bari, via Orabona 4, 70126, Bari, Dipartimento di Ingegneria Civile, Ambientale, del Territorio, Edile e di Chimica, DICATECh

Pianificazione e trasformazione urbana, ingegneria del territorio;
Applicazione di processi di interazione cognitiva strutturata per l'uso ed il governo del territorio mediante approccio ontologico e definizione di mappe cognitive al fine di costruire gli ambiti di rischio a livello urbano e le connessioni tra gli stakeholder. Caso studio: città di Bari
Relatore: Domenico Camarda, ordinario Ingegneria del Territorio

Laurea Triennale

Politecnico di Bari, via Orabona 4, 70126, Bari, Dipartimento di Ingegneria Civile, Ambientale, del Territorio, Edile e di Chimica, DICATECh
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Caso studio: città di Giovinazzo
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