Assessing urban vulnerability related to flash floods under climate change conditions in Istanbul, Turkey

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by

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Abstract

Urban areas in many parts of the world are more likely to be affected by the effects of climate change. Because of this, different urban vulnerability assessments have been developed in order to determine which areas are more vulnerable and therefore can be prioritized by policy-makers and governments. However, these assessment studies have focused more on particular hazards without relating it to climate change. This lack of linkage to climate change constitutes a problem, especially in Istanbul, which is expected to suffer from flash flood events as a consequence of climate change. This, together with the weaknesses that the already applied frameworks in vulnerability assessments in Istanbul present such as considering either physical or social vulnerability, call for a need to develop and apply a new framework to assess vulnerability at the local level under climate change conditions.

The purpose of this research was to theoretically develop and to apply a framework using local knowledge aimed to assess urban vulnerability at the local level related to flash floods under climate change conditions in Istanbul. For this, two neighborhoods within Ayamama river basin: Ikitelli Mehmet Akif and Ikitelli Atatürk, in Küçükçekmece district, in Istanbul, were selected as case study area.

Survey questionnaires applied through interviews were the chosen method to access and collect local knowledge, from which proxy indicators were developed. These were then combined with other parameters from existing literature to develop the framework. These parameters served as input to calculate a vulnerability index using Spatial Multi Criteria Evaluation (SMCE) in ILWIS. Results show that local knowledge in the study area was useful for comprehending the context regarding vulnerability. Also, that vulnerability in the study area is high, with values ranging between 0.79 and 1. The application of the framework in the study area was not exempted of shortcomings which were related to data scarcity, spatial scale, and participation from local people. All these issues as well as the applicability of a framework like this in a developing country are discussed.

Key words: climate change, flash floods, vulnerability framework, local knowledge, urban vulnerability assessment, SMCE.

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1. Introduction

This chapter describes the background and significance of the research, the research problem, research objectives and questions, as well as the research approach. It also presents the thesis outline.

1.1. Background and significance

Climate change constitutes a challenge for scientists, policy-makers, and common people since extreme weather events (floods, draughts, heat waves and sea level rise) seen as climate change impacts will harm people differently worldwide (IPCC, 2007a). In this sense, floods constitute a natural hazard that affects many areas throughout the world. They will have more or less impact depending on the area's exposure to such hazard and its socio economic characteristics. The IPCC (2007a) expects that, under climate change conditions, more intense short-duration precipitation in Europe will occur, leading to a higher risk on flash floods, which are sudden events with a rapid and violent movement of water in a small spatial area. These particularities make their warning a difficult task (Montz and Gruntfest, 2002), especially in Mediterranean countries, where flash floods are more intense than in the rest of Europe (Gaume et al., 2009). In this region, urban areas, located nearby rivers, are considered to be vulnerable to this hazard due to their distance to the riverbed, and their high and continuously increasing population and population density, just to mention a few factors. In this sense, vulnerability arises as a complex and critical factor related to the impact of flash floods.

Vulnerability is an issue that has been broadly researched (Uitto, 1998, Adger, 1999, Kelly and Adger, 2000, Moss et al., 2000, Cross, 2001, Bohle, 2001, Few, 2003, Pelling, 2003, Cutter, 2003, Füssel, 2007). In urban environments, vulnerability is understood as a condition that shows how deficient and susceptible the urban environment is to be damaged "due to social, biophysical, or design characteristics" (Rashed and Weeks, 2003, p.550). Every research requires first to conceptualize "vulnerability". That implies understanding all the elements that integrate the concept and how they are interrelated. Every vulnerability conceptualization developed is presented in what is called a framework which helps visualize and understand the interrelationships within each vulnerability model (Birkmann, 2006). Applying any particular framework in order to assess vulnerability implies having specific scope, following a series of organized steps and using a series of tools and analysis that constitute the approach. Many approaches have been developed (Behringer et al., 2000, Belton and Stewart, 2002, Dessai and Hulme, 2003, O'Brien et al., 2004a, Pittman et al., 2011), and applied in different contexts; however, most of the researches fall within the risk and hazard category.

Urban vulnerability assessment studies have so far focused on particular and specific hazards such as floods, identifying physical, and or social vulnerability (Ebert and Kerle, 2008, Marschiavelli, 2008, Wigati, 2008). These kinds of assessments are important for disaster management since one can know where vulnerable areas and groups are located (Birkmann, 2007). Thus, vulnerable areas and groups can be prioritized on disaster-management plans.

Within vulnerability to climate change frameworks, assessments *do* consider the impacts of climate change, and they have been developed in order to determine and analyze how people will respond and adapt to changes in the environment (Hahn et al., 2009). These vulnerability assessments see flash floods as a consequence of climate change, and therefore, its implementation becomes important in urban planning.

In Istanbul, few studies are placed within the social and physical approach (related to a particular hazard). For instance, Haki et al. (2004) developed a methodology to identify vulnerable groups to earthquakes according to their social characteristics. Ozcan and Musaoglu (2010) determined the vulnerability of settlements to floods according to their distance to the riverbed and other physical parameters within the Ayamama river basin. Although these assessments have produced good results regarding vulnerability, they present some disadvantages such as the exclusion of social variables in the study of Ozcan and Musaoglu (2010). In cases in which the social dimension was addressed, the approach did not include the involvement of local people, considering people's perception about the hazard by which one can get to know more the "human behaviour" (Rashed and Weeks, 2003, p.547). This first-hand information such as local knowledge says a lot about how the inhabitants might respond and adapt to a flood event. Moreover, this and other assessments have not considered the hazard events as a consequence of climate change. This lack of linkage to climate change constitutes a problem, especially in Istanbul, which is expected to suffer from flash flood events as a consequence of climate change due to its location in the Mediterranean region.

Finally, assessments to climate change in Istanbul will give information about the most important factors that determine vulnerability, as well as the spatial distribution of vulnerable groups. This information can be used to shape decisions made by urban planners and policy-makers in order to increase the current adaptive capacity, and to reduce the current exposure and sensitivity of the study area to climate change impacts, especially flash floods. Moreover, vulnerability assessments to climate change can be used to estimate future vulnerable conditions and, therefore, plan an adequate response.

1.2. Research problem

Urban vulnerability assessments conducted in Istanbul are placed within a social and physical approach. Their focus is mainly on physical parameters without taking into consideration the human component, or on social aspects but not involving local people's knowledge within a participatory approach. Second, they also fall within a hazard and risk perspective, relating vulnerability to particular flood hazards without a consistent linkage to climate change.

Due to the fact that the occurrence of flash floods will increase in the area (IPCC, 2007a) and to the absence of an appropriate applied vulnerability framework in Istanbul, there is a need to develop and apply a new framework to assess vulnerability within climate change at the local level. This new framework and the way of applying it should constitute the result of adapting the best of previous frameworks which take into account local knowledge and climate change.

Developing and applying a new framework gives results not only on the vulnerability assessment itself (that explains the location and causes of vulnerability areas and groups) but also on how realistic the chosen framework and the steps to downscale it are. It may be that a framework might work for some areas but not for some others. With all these feedbacks, a more accurate vulnerability framework and approach are improved and can be further developed in future researches.

1.3. Research objectives

1.3.1. General objective

To theoretically develop and to apply a framework using local knowledge aimed to assess urban vulnerability at the local level related to flash floods under climate change conditions in Istanbul.

1.3.2. Specific objectives and research questions

1. To analyze different approaches to assess vulnerability.
   - What are the existing approaches to assess vulnerability?
   - What is the role of participatory approaches?
   - What is the role of stakeholders in assessing vulnerability?

2. To elaborate a new framework to assess vulnerability related to flash floods under climate change conditions at the local level.
   - What is the contribution of this framework to assess vulnerability at the local level?
   - What are the factors (measures) that contribute to urban vulnerability in the area?

3. To discuss the role of local knowledge in an urban vulnerability assessment related to flash floods under climate change conditions.
   - How can local knowledge be included in the assessment?
   - What do people perceive about floods and climate change?

4. To apply the defined framework to assess urban vulnerability at the local level in Istanbul.
   - How can this framework be applied in a particular urban context?
   - What are the shortcomings when applying this framework in Istanbul?

1.4. Research approach

Figure 1-1 shows the main steps involved in the research. It starts with the research problem definition considering vulnerability assessments, climate change and flash floods in Istanbul. The study presents a strong discussion part regarding the main points such as vulnerability frameworks and approaches which will assist in the definition of a new framework, and how to apply it in order to assess vulnerability at the local level. This framework incorporates exposure, sensitivity and vulnerability as part of its vulnerability comprehension and assumes the use of local knowledge through participation. The framework is later applied in a study area composed by two neighborhoods in Küçükçekmece district in the European part of Istanbul: Ikitelli Mehmet Akif and Ikitelli Atatürk which are located within Ayamama river basin. Results are analyzed and discussed again using scientific literature and fieldwork observations.

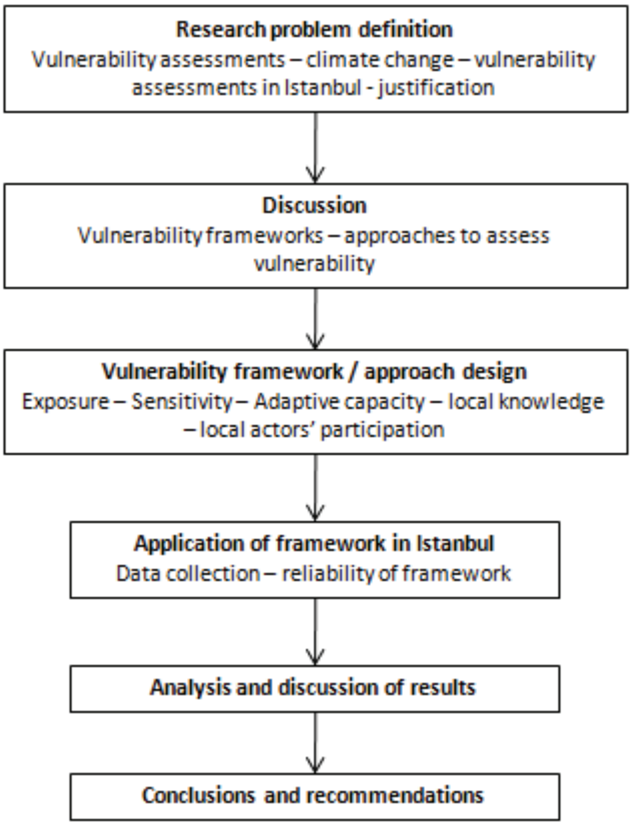

Figure 1-1 Research approach flowchart

This thesis is organized in 7 chapters. Chapter 1introduces the main topic of research related to climate change and urban vulnerability assessments; presents the research problem as well as objectives and the research approach. Chapter 2 reviews and discusses the main concepts of research. Chapter 3 describes the methods used to fulfil the objectives, and the case study area. Chapter 4 describes the urban flash floods under climate change conditions vulnerability framework and approach based on local knowledge and existing literature developed for this research. Chapter 5 is devoted to the application of this framework to assess vulnerability in the study area, and results are discussed in chapter 6. Finally, chapter 7 presents the conclusions and recommendations from the research.

2. Literature review

This chapter reviews previous literature regarding the main topic of this research. It discusses the main concepts: climate change, flash floods, vulnerability, and vulnerability assessment approaches with special focus on participatory approaches.

2.1. Climate change and flash floods in Turkey

Climate change is understood as a modification in the present condition of the climate by the “changes in the mean and/or the variability of its properties” which last for a period of time (IPCC, 2007b, p.667). Nations, depending on their geographic location, will experience floods during winter; warmer summers and coastal areas are likely to suffer from sea level rise (IPCC, 2007a).

For Turkey, models predict a change in the seasonality of precipitation meaning that they will either start one month in advance or one month later, requiring adaptations to this new “calendar” (Güven, 2007). This “new” seasonality is expected to increase the frequency of flash floods and urban areas are more likely to be affected. Because of that, Turkey has started to develop different measures to adapt to climate change effects which include an increase in participation and public awareness on disasters associated to climate change (Turkey: Ministry of Environment and Forest, 2010).

Flash floods are characterized by a rapid and violent movement of water in a small spatial area produced by heavy rainfall. During a precipitation event, there is a short time span between the storm peak and the discharge stream peak. Urbanization reduces the infiltration capacity of soils and reduces the time period between the two peaks. Thus, flash floods are more likely to occur in urban areas, where soils have been progressively replaced with concrete and other man-made features (Figure 2-1).

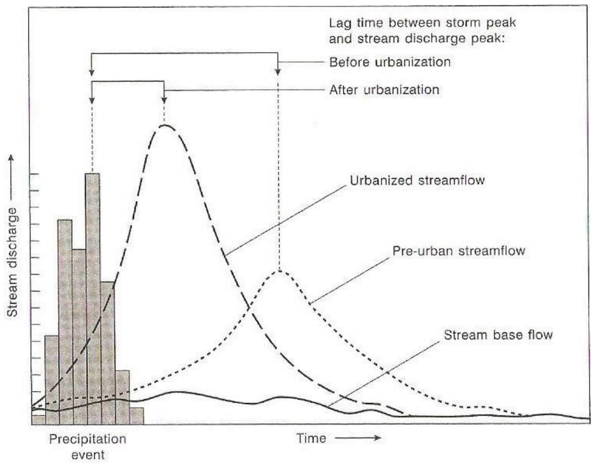

Figure 2-1 Pre and post urbanization storm and discharge peak (White, 2010).

During the 1950 – 2010 period, Turkey has experienced 35 flood events (EM-DAT, 2010). Part of Istanbul is located on flood –prone areas, where flood events have already occurred. Here, a combination of different factors such as unplanned urbanization, an increase in population density, weak construction control by the authorities (Yalçin and Akyürek, 2004), deficient urban master plans and heavy rainfall have caused floods with severe economic and social losses (Yalçin and Akyürek, 2004, Einfalt and Keskin, 2010, Dubovyk, 2010).

Flood events in Ayamama river basin happened in 1995, and 2002. The lack of mitigation measures and implementation of new disaster policies after the 2002 event have enlarged the negative consequences of September 2009's flash flood: 31 people killed (Reza, 2009, Watson and Comert, 2009) and a loss of more than $100 million (Yildiz, n.d.).

2.2. Vulnerability

The term "vulnerability" has been broadly defined and has evolved along the years (Pelling, 2003, UNDP, 2004, Birkmann et al, 2006). From a more limited conceptualization based only on the likelihood to experience damage, vulnerability has been widened including more concepts such as exposure, coping capacity, and is, in the present, a multidimensional term (Birkmann, 2007). All these variations can be seen in the different vulnerability frameworks in which the term is explained.

For instance, Bohle (2001) understood vulnerability as a double structure concept with an internal and external side. The former is related to the coping capacity needed to withstand the impacts of hazards; the latter focuses on the exposure to risks. Therefore, vulnerability depends on the interrelationship between these two sides and cannot be explained without the presence of any of them.

Within a hazard and risk approach, Birkmann (2006) summarized two of the most important frameworks such as the one developed by Davidson in 1997 and Bollin et al in 2003. Contrary to Bohle's framework, here, disaster risk constitutes the core of the conceptualization, and vulnerability is seen as one of its four components together with hazard, exposure, and capacity and measures. A peculiarity is that in this framework, exposure and capacity –also identified in Bohle (2001)- do not seem to interact within the vulnerability component, and that represents an issue that has been covered by posterior approaches.

A more complex framework called the BBC framework was developed by Bogardi/Birkmann (2004) and Cardona (1999/2000). It considers three aspects of vulnerability and risk: environmental, social and economic; and identifies that in order to reduce vulnerability, one should focus also on coping capacities and intervention tools (Birkmann, 2006).

When focused to climate change, vulnerability is understood as "the degree to which a system is susceptible to, and unable to cope with, adverse effects of climate change, including climate variability and extremes. Vulnerability is a function of the character, magnitude, and rate of climate change and variation to which a system is exposed, its sensitivity, and its adaptive capacity" (IPCC, 2007c, p.21). On the one hand, exposure refers to the frequency and magnitude to the climate–related hazard such as floods. It is considered as a "product of physical location and the character of the surrounding built and natural environment" (Pelling, 2003, p.48); therefore, it is studied by considering physical parameters such as topography, distances, temperature, precipitation, etcetera. On the other hand, sensitivity considers how a population is sensitive to changes in the climate (Ebi et al., 2006) due to its intrinsic structure such as demographic profile, for instance.

From the three components of vulnerability: exposure, sensitivity, and adaptive capacity, it is the latter the one which influences the most the degree of vulnerability. According to IPCC (2007c), adaptive capacity recalls on how capable a system adjusts itself to climate change by responding to its effects. In the case of a society, this condition depends on several factors such as socioeconomic conditions, technology and infrastructure, institutional framework, knowledge, among others (Metzger et al., 2005). These set the framework in which different adaptation actions, which are the materialization of adaptive capacity, are generated (Smit and Wandel, 2006). For example, if two groups of people –A, with good education, access to information and a good economic condition; and B, with low education level, no access to information and a deficient economic condition- were equally exposed and sensitive to a hazard under climate change conditions, A would be less vulnerable than B due to its higher adaptive capacity: its good socioeconomic condition will make it respond and adapt better than B to the effects of climate change by either developing short or long-term actions.

Turner et al. (2003) coincide with the above definition of vulnerability; however, in their vulnerability framework, they have imported the term "resilence" from ecology to refer to the coping response or adjustment of the "human –environment system" to an event. Resilence, thus, is in this case nothing else but adaptive capacity. Their framework considers stressors inside and outside the system which could be human-social and environmental changes, both having influence in the exposure.

Metzger et al. (2005) also based their framework on the IPCC conceptualization of vulnerability. Within their vulnerability of terrestrial ecosystems framework, their understanding of exposure could be seen as more "chemical" because they include climate change –quantified using global change scenarios-, nitrogen deposition and atmospheric composition. While this approach considers the mentioned items as components of exposure, Turner et al. (2003) would identify these as stressors influencing exposure, in other words, as something external and not as components.

So far, vulnerability frameworks have focused on the interrelationships of the different concepts that compose them. Nevertheless, a special vulnerability framework is presented by Polski et al. (2007) who state that it is even more important the integration of methodologies from different research fields for assessing vulnerability to climate change. Therefore, their framework is presented in a more user –friendly way. The Vulnerability Scoping Diagram (VSD) constitutes a tool that enables comparability between vulnerability assessments. Its structure includes the following parts: dimensions, components, and measures. The IPCC vision of vulnerability is included in dimensions since these are exposure, sensitivity and adaptive capacity. Components are the abstract characteristics to be evaluated on every dimension, and measures are the quantifiable elements of each component. Since Polski et al. (2007) pay attention to the methods more than to the conceptualization of vulnerability, one of the advantages of this framework is explained by the fact that it is not static, meaning that it can be updated. Researchers using the VSD approach can update it with local knowledge from local people applying different group techniques. This characteristic places this framework in a participatory environment in which local knowledge and comprehension of the community are crucial for the vulnerability assessment (Birkmann et al., 2006).

The Livelihood Vulnerability Index (LVI) proposed by Hahn et al. (2009) can be seen as an application of the VSD. Although the LVI does not use these exact terms of dimensions, components and measures, it uses the three levels of organization of the VSD. The LVI is then calculated by a formula:

$$\text{LVI} - \text{IPCC}_d = (e_d - a_d) * s_d$$

, where "e", "a" and "s" correspond to exposure, adaptive capacity and sensitivity, respectively. These are the components that IPCC considers as vulnerability and the reason of the presence of this acronym in the equation. Exposure is measured by natural disasters and climate variability; adaptive capacity by the demographic profile, livelihood characteristics, and social networks; and sensitivity by the state of food, water security and health status.

Finally, Wilhelmi and Hayden (2010) focus on adaptive capacity but more from a methodological perspective. They address not only a sound conceptualization of the different elements that interact and compose vulnerability but also pay attention to the fact that a combination of quantitative and qualitative analysis will lead to a more appropriate vulnerability assessment. In their framework, vulnerability is influenced by external drivers such as climate change and urbanization which may increase exposure; and, is at the same time, affected by adaptation and response measures, which are directly related to adaptive capacity.

2.3. Vulnerability assessment approaches

Vulnerability assessments join various methods, which come from different sciences, to identify how the relation of the three components mentioned above is, and they have been applied in multiple situations (Hinkel, 2008, Hahn et al., 2009). This variety depends on the scale and unit of analysis, time span, understanding of vulnerability, selected tools, among others (Dessai and Hulme, 2003). It is important to revise and comprehend these approaches in order to propose an optimal vulnerability at the local level framework and apply it in Istanbul.

2.3.1. Social and physical approaches

This distinction is made focusing on the object of study. While social approaches to assess vulnerability focus more in the analysis on the socio-economic characteristics such as demographic profiles and income of societies, physical approaches prioritize the analysis of physical exposure in terms of infrastructure, and does not include human groups into their assessments (Dessai and Hulme, 2003).

A wide variety of researches has been developed within these approaches (Adger, 1999, Haki et al., 2004, Sagala, 2006, Ebert and Kerle, 2008, Marschiavelli, 2008) and shows the importance of each one of them. Nevertheless, both kind of aspects need to be included in a proper assessment since an area is a combination of both: physical space and social groups that live on it.

2.3.2. Start-point and end-point approaches

The main concern within these approaches is whether vulnerability determines adaptive capacity (start point) or the latter determines the former (end point) within a climate change context. In the start point, assessments seek to understand where and why vulnerability exists in order to elaborate measures to reduce vulnerability, and increase adaptive capacity. However, the end point approach considers that climate change impacts modify people's adaptation, and consequently, vulnerability (O'Brien et al., 2004a).

2.3.3. Top-down and bottom-up approaches

A top-down approach uses general world climate change scenarios to identify the potential impacts or vulnerabilities in an area. This type of vulnerability tends to be related to a physical approach and end point approaches (Dessai and Hulme, 2003). Whereas, bottom-up approaches have a more social aspect focusing on adaptive capacity in order to determine vulnerability. They are more related to social vulnerability and start point approaches (Dessai and Hulme, 2003, Pittman et al., 2011).

2.3.4. Multi criteria evaluation approaches

MCE, also called multi criteria decision analysis or decision making, refers to the same concept understood as a group of approaches that incorporates different criteria interrelated among them in order to help decision –makers find the optimum alternative for a particular problem (Belton and Stewart, 2002, Aceves-Quesada et al., 2007). The usefulness of this approach is based on its good relationship with the rest of approaches. Usually, MCE has been combined with GIS (Malczewski, 1996) in order to estimate vulnerability in a spatio-temporal scale and it is used for different purposes such as natural resource management, hazard and disaster management, and ecology (Mendoza and Martins, 2006).

2.3.5. Participatory approaches

A common characteristic in the vulnerability assessments that have been examined is the focus in the local level, either households, communities or districts (Yalçin and Akyürek, 2004, Haki et al., 2004, Ozcan and Musaoglu, 2010). In order to assess vulnerability at the local level, information -at the same level- is necessary but it is often unavailable. In many countries, census data are processed considering the district or neighborhood as the minimum area of analysis; however, what if the study focuses on small rural communities in a mountainous region with little accessibility?, what if the study requires to spatially subdivide a district, therefore, census data at this level needs to be disaggregated? Here, information would need to be obtained in a different way.

Approaches that include the role of local actors involving their perception, local knowledge and experiences (Behringer et al., 2000) in order to obtain information are considered to be participatory. They enclose a variety of tools which help the researcher identify key issues at the local level. According to van Aalst et al. (2008), these are:

- Sketch mapping, in which elements of interest are drawn by local people with detail.
- Historical calendars, in which people are asked to remember and mention past events such as hazards.
- Transect walks, in which researchers walk with local people to identify points of interest for the specific study.

Other tools included are rapid inventories, household surveys, key informant interviews, survey questionnaires, focus group meetings as well as stakeholder participation (Barahona and Levy, 2007, van Aalst et al., 2008).

Participatory approaches have been used in many fields and for different scopes such as forest management (Mendoza and Prabhu, 2005), land use planning (Hessel et al., 2009) and GHG emission reduction (Stalpers et al., 2008). However, special attention will be given to the field of vulnerability, risk and hazard assessment.

Participatory approaches in the field of vulnerability, risk and hazard assessment focus on people's experiences. In this sense, van Westen (2009) considers that working with local people in local communities will have as a result good information at local level since they are the ones who know the best the hazards that affect them, the elements at risk, the consequences of the events, as well as the adaptive mechanisms they employ. Therefore, this information could be incorporated into disaster management plans. Participatory assessments, help people become more aware of their vulnerabilities, having a positive impact in preparedness and reducing the impacts of the hazard (Zein, 2010).

Mustelin et al. (2010) addressed current and future vulnerability related to coastal change by combining stakeholders' perceptions through interviews and vulnerability mapping. This contributed to develop a management strategy for coastal forest areas.

Peters-Guarin (2008) included a participatory approach based on people's perception of flood risk inside a community flood risk assessment. In this study, the inclusion of GIS represents a plus because Participatory GIS (PGIS) "involves communities in the production of spatial data and spatial decision-making" which can be modified or updated by them in a GIS (Peters-Guarin, 2008, p.34). This is an innovative method that continues to be developed together with the application of GIS in many sciences.

Participatory approaches have been included within vulnerability to climate change frameworks since these focus on people's adaptive capacity (see Section 2.2): the capacity to adapt to climate change effects starting from what people perceive about this topic (Behringer et al., 2000), and ending with a link to local level decision-making in the design of adaptation measures (Næss et al., 2006). In this line of work, Schröter et al. (2005) proposed and developed an eight-step methodology for vulnerability research. This approach is structured in two main phases: pre-modeling and post modeling. While the first one groups the area, scale and stakeholders selection; study area exploration and stating the hypothesis regarding who is vulnerable to what; the second phase includes the development of a vulnerability model as well as the different indicators for each component: exposure, sensitivity, and adaptive capacity. It also considers the correct weighting and combination of indicators as well as the projection into the future with the use of scenarios. Finally, the last step requires communicating the results to all stakeholders involved in the process.

2.3.5.1. Stakeholders in participatory approaches

People who are concerned about flash floods as a consequence of climate change may be considered as stakeholders. Giordano et al.(2007) see stakeholders as both individuals and organizations involved in the decision making process. Therefore, they should be included in defining and evaluating all possible alternatives. Stakeholders are important since they provide local knowledge and their own experience to the assessment, which can be combined with scientific knowledge in order to produce a better understanding of vulnerability to flash floods.

One issue regarding the incorporation of stakeholders into the assessments is how to convert local knowledge –which is basically qualitative information- into quantitative information that can be relevant for external actors (researchers) as inputs for the assessments (Peters Guarin et al., 2008). The assessment of vulnerability requires the analysis of different factors that contribute to this state. These factors are combined in a MCE to produce a final vulnerability output.

Smith et al. (2000) and Raaijmakers et al. (2008) proposed methods to weight every factor of the vulnerability in the MCE based on people's perception. People who were interviewed had to complete two tasks: first, to identify all the vulnerability factors; and second, to rank them in order of decreasing importance. In some cases, they had to add a numerical value to each factor. People's opinion about every factor was later transformed using an index method, and incorporated into the MCE. Vulnerability assessments using participatory weighting definitely gives different outputs when compared to weights given by experts or researchers. This does not mean that one is more important than the other one, but the former could be considered more realistic since it incorporates "direct user's" knowledge.

2.3.5.2. Challenges in participatory approaches

Participatory approaches may face many challenges: van Westen (2009) affirms these approaches receive critics due to the fact that they are considered as subjective since they rely on local knowledge, which is based on perception. This is true. Interviews, questionnaires and sketch mapping rely on information given by people. However, this does not mean that this information cannot be cross checked with other methods. For example, information regarding flood extension can be validated with fieldwork and satellite images.

These approaches demand a considerable amount of time (van Aalst et al., 2008). People have different backgrounds and different education level; thus, the researcher cannot assume that people would understand at first the methodology to be implemented. Moreover, if, for example, transect walks are going to be used, the researcher needs to spend time in the community in order to walk and reach all the important spaces for the study.

In many cases, reaching urban or rural communities require special authorization from the local government. This represents itself a time-demanding task but it needs to be considered in order to develop the methods.

Finally, participatory approaches have shown to have a broad spectrum of applications. Not only have they been used for decision-making but also for producing information where it is unavailable, in some cases even national statistics have been developed when combined appropriately with statistical principles (Barahona and Levy, 2007).

This chapter showed how vulnerability assessments may be developed using different approaches/methodologies. Despite this, there are studies in which many of these approaches –at least parts of them- have been combined in order to assess vulnerability. For instance, Peters-Guarin (2008) estimated vulnerability in Naga City, Philippines, by combining a physical, social, participatory, and MCE approach. The base of her research was people's perception about flood risk which was obtained through participatory tools such as focus group discussions with people and officers. Surveys were also applied in order to improve and obtain exact information about livelihood, health, education, access to basic services, housing, which were found as factors that influence household vulnerability. Since the location of the surveys was georeferenced, it was possible to identify the spatial distribution of the different factor values that influence vulnerability. In order to integrate this data to estimate vulnerability by Spatial MCE, they were standardized and each factor was assigned a weight value. The weight values were given by local people, making this assessment more reliable since the importance of every parameter was given by the inhabitants themselves. Finally, results were presented in the form of maps.

Vulnerability assessments seek to identify which areas and groups are more vulnerable. This task demands effort, time and economic and human resources. Their results, either in the form of maps (Haki et al., 2004, O'Brien et al., 2004b, Marschiavelli, 2008, Peters Guarin et al., 2008) or tables (Hahn et al., 2009) can be used by policy-makers, institutions involved in mitigation or the government to prioritize areas in which special attention is required or to develop preparation actions (Hinkel, 2011).

3. Research methodology

This chapter presents the methodology followed in this research including the method overview, case study area selection, data collection, and method for vulnerability assessment calculation.

3.1. Method overview

Figure 3-1 shows an overview of the research. It starts with a thorough review of literature focusing in different vulnerability frameworks such as those focused on hazard-risk, and those on climate change. Vulnerability approaches are also reviewed to understand different ways of developing frameworks and how they analyze vulnerability. This discussion serves as input for a first understanding of urban vulnerability related to flash floods under climate change conditions prior to the fieldwork phase.

Data collection in the study area is developed using survey questionnaires applied through interviews to in order to get relevant primary and secondary data to fill the framework. On the one hand, the results, obtained from primary data collection, comprise local knowledge, which is analyzed to build proxy indicators. These contribute to adapt the first draft to a particular framework to assess urban vulnerability related to flash floods under climate change conditions using local knowledge. On the other hand, a GIS analysis is applied especially to topographic data in order to create some inputs which are necessary for the spatial multi criteria evaluation (SMCE). Socio economic and meteorology data are also incorporated in the preparation of for the SMCE. Finally, all the layers will be combined in order to estimate urban vulnerability at the local level.

Next, the research focuses more in the discussion. First, discussing the final framework, its structure (dimensions, components, and measures) and justifying every choice is necessary. The results of the vulnerability assessment as well as the approach utilized, framework applicability and reliability for this study area, including fieldwork observations are discussed. Finally, conclusions from the research are drawn and recommendations for future research in urban vulnerability in Istanbul are made.

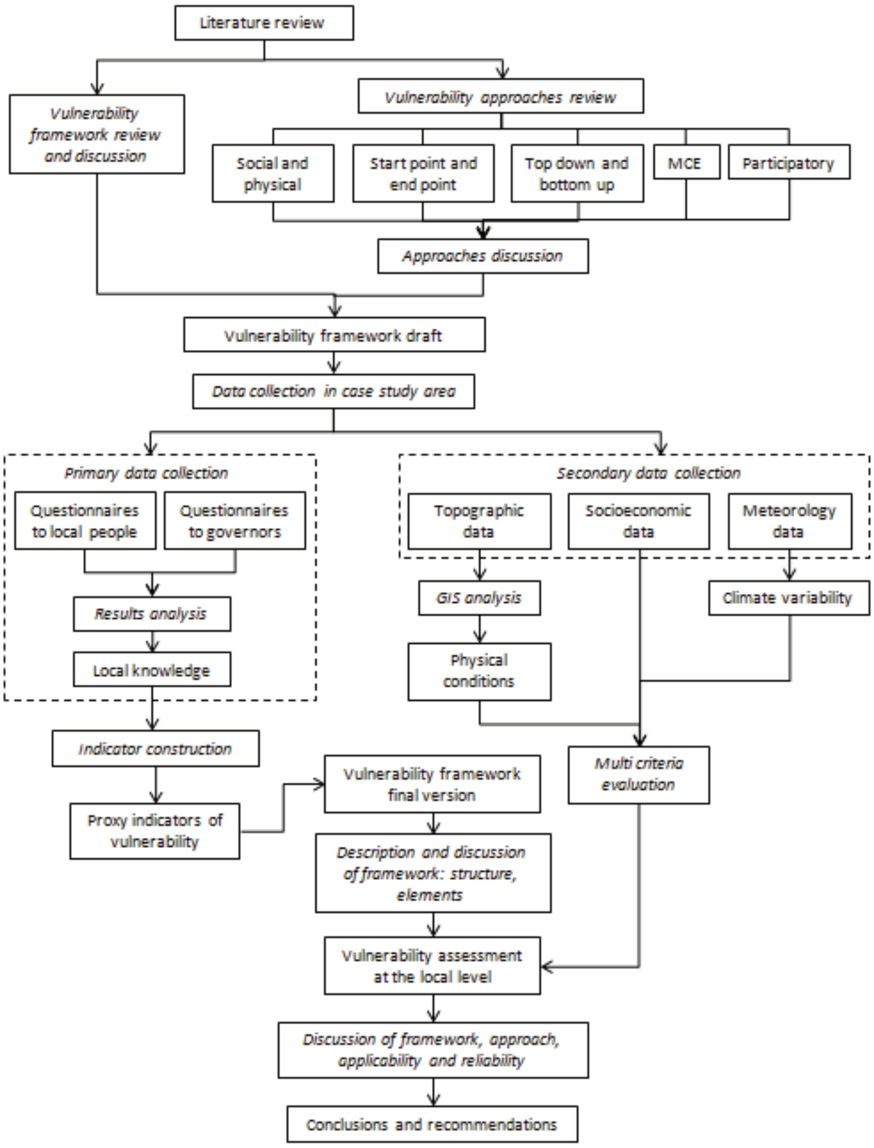

Figure 3-1 Methodology overview

3.2. Study area selection

The case study area for this research is Ayamama river basin located in Istanbul, the largest city in Turkey with a total population of 12 915 158 inhabitants (Turkish Statistical Institute, 2010). Ayamama river basin has an area of 62.27 km^2 and it encompasses 25 neighborhoods within the Bağcilar, Bahçelievler, Bakirköy, Başakşehir, Küçükçekmece, and Sultangazi districts (Figure 3-2). The river flow has a north-south direction and discharges into the Marmara Sea (Einfalt and Keskin, 2010). In the upper part of the basin, the river presents more tributaries than in the middle and lower parts due to less built-up areas in the north. Also because in the middle and lower part it has been channelized, and in some sections covered for urbanization.

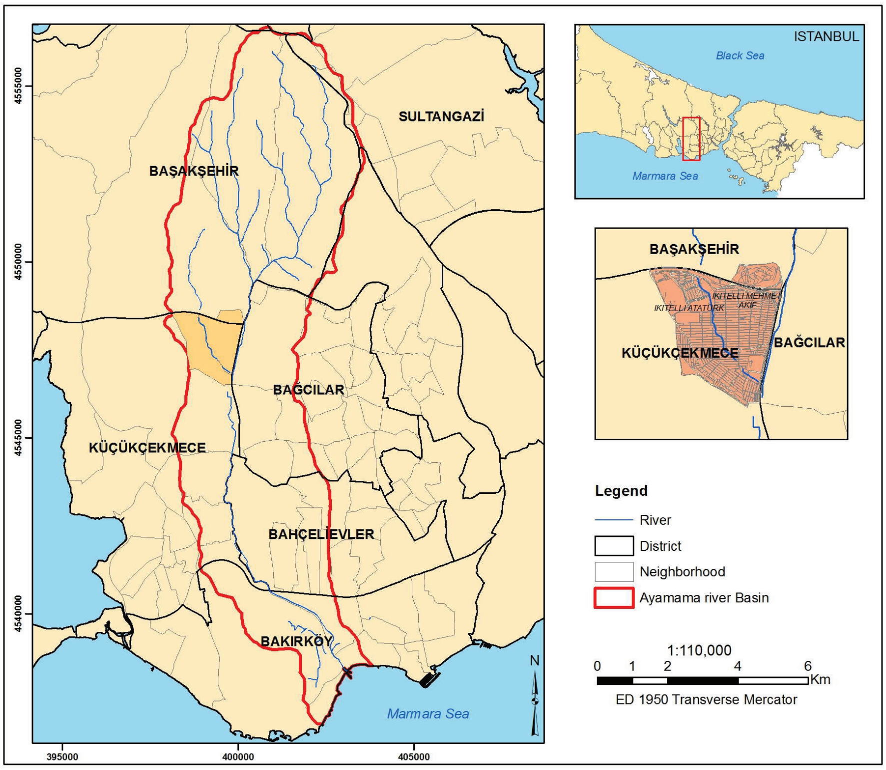

Figure 3-2 Study area

The area where the basin is located has experienced a process of rapid land cover change in the last decades: bare soil areas, grasslands and shrubs (some of them still present in the upper part of the basin) have been progressively replaced with built-up areas (Figure 3-3) designed for densely residential and industrial uses (Kaya and Curran, 2006, Kucukmehmetoglu and Geymen, 2009). This has been reported to constitute a threat since many of the industries located along the Ayamama river throw part of their wastes to the river, and people do the same with their solid garbage[1]. There is no specific information about the increase in built-up areas for the study area; however, for Istanbul, it has increased in 126.7% between 1987 and 2001 (Kaya and Curran, 2006).

Figure 3-3 Residential mixed with industrial areas in Ayamama river basin

Population within Ayamama river basin is approximately 799,556 inhabitants[2] (IMP, 2006). The most populated neighborhoods are Halkali Merkez and Inönü, in Küçükçekmece district; and Zafer in Bahçelievler district, located in the middle part of the basin (Figure 9-1 in Appendix A). Population in the upper part of the basin is less since these neighborhoods are not completely urbanized and still have natural land cover.

From the 25 neighborhoods in the basin, 2 have been particularly selected as the case study area: Ikitelli Mehmet Akif and Ikitelli Atatürk (45,265 and 38,911 inhabitants, respectively) located in the north east limit of Küçükçekmece district. First, although Ayamama river does not go through these neighborhoods, it was seen that the stream in the form of a channel that administratively divides both areas also constituted an exposure to a flash flood event (Figure 3-4) and was one of the reasons why they were affected during the flash flood in September, 2009.

Second, along Ayamama river the most common urban feature is represented by factories and spaces that serve as parking lots for trucks. Since they are private properties, interviewing people inside would have been very complicated despite the fact that they suffered serious damages due to the flooding. Moreover, the objective was to work with local inhabitants and these areas do not have residential use. The 2

[1] This was observed during fieldwork in September, 2010.

[2] Population values given correspond to the values for the entire neighborhood and not just the portion of neighborhoods within the basin.

chosen neighborhoods are mainly residential and commercial; therefore, local people are, in principle, more reachable than in the rest of neighborhoods.

Finally, Ikitelli Mehmet Akif and Ikitelli Atatürk, like many of the neighborhoods in the basin, have a poor drainage system that fills up and spills during heavy rainfall periods. This affects the mobility of people in the streets. It also affects houses/buildings that present a bottom floor –reached by stairs- at a lower level than the street. These areas function not only as residences but also as small industrial business such as textile, paper, and etcetera. For the reasons discussed, these neighborhoods have been considered as representative of Ayamama river basin and research will be focused here.

Figure 3-4 Residential areas in Ikiteli Mehmet Akif and Ikitelli Atatürk

3.3. Primary and secondary data collection

Primary data collection was developed in Ikitelli Mehmet Akif and Ikitelli Atatürk neighborhoods in September-October, 2010. Initially, household survey questionnaires were thought to be used in order to collect information regarding demographic and socio economic issues at the household level since these kinds of questionnaires have been used for the same purposes with good results (Barahona and Levy, 2007, Hahn et al., 2009). These data per household would have allowed the identification of the distribution of vulnerability in the area since every household would have been georeferenced with GPS. However, once in the field, it was seen that the household universe was too numerous consisting of 14,854 households (IMP) and would have been impossible to get a representative sample in the time left.

The structure of the survey questionnaire was changed and it was decided not to apply it at the household level because of time and other issues (see Section 3.5).

The aim of the survey questionnaire was to gather information regarding vulnerability, flash floods, climate change, and adaptation measures from the inhabitants of the two chosen neighborhoods. It was applied using the “personal interview method” because better quality answers can be obtained, and the interviewer can encourage his participation by motivating and explaining each question to the interviewee (UNO, 2008). The questionnaire (Appendix B in Section 9.2) was originally prepared in English and then translated into Turkish.

Target population was composed by residents who were outside their houses, and shop owners since both groups of people could be easily and directly reached from the street, along the river channel, within 100 meters, because it is the most affected area when a flood occurs. However, due to missing people to be interviewed, a few of them were done outside this area (Figure 9-2 in Appendix A). The location of every questionnaire applied through interview was georeferenced with a Mobile GIS (IPAQ) connected to a GPS. Based on Mustelin et al. (2010), children and teenagers were excluded from the target population since it was assumed that the longer time living in the area, the better it is because people know the place and they give more interesting answers than someone who has been living there for a shorter period of time. A local Turkish – English translator approached a potential interviewee and asked him/her if he/she wanted to participate and collaborate. If the person accepted, the questionnaire was filled in Turkish; and if he/she refused, translator asked another potential participant, and so on. Finally, the sample consisted of 30 interviews -15 in each neighborhood- because not all of them wanted to participate.

It was also decided to apply the same questionnaire with a few variants (Appendix C in Section 9.3) to the governors of both neighborhoods (“muhtars” in Turkish) because, as local authorities, they are in direct contact with residents and have more knowledge about issues related to the neighborhood. Moreover, they are the nexus between the neighborhoods and the district. Mr. Naim Kangal and Mr. Mehmet Polat were interviewed in their offices in Ikitelli Mehmet Akif and in Ikitelli Atatürk, respectively. Each interview took approximately 10-15 minutes. Finally, one day after the questionnaires were filled, all the answers collected were translated back into English and organized in an Excel spreadsheet.

Secondary datasets were obtained from different sources and included survey, spatial, census and meteorology data (Table 3-1). Socio economic and demographic data was obtained from a 255 403 sample household survey conducted in 2006. Although it was designed for transport purposes, it considered several indicators such as: total population, population per sex, population per age group, literacy, and population per education level, useful for this research. Spatial data was obtained from the GIS Department of IMP and consisted in 5 meters isolines, hydrographic network and the new administrative boundaries recently modified in 2008. All datasets were standardized into ED 1950 Transverse Mercator to avoid data shifting. Household size per neighbourhood was obtained from Turkish Statistical Institute from the 2009 Population Census, and meteorology data was obtained from Florya station, located in the lower part of Ayamama river basin, the only gauge station in the basin.

Table 3-1 Secondary data

Type of data	Level of detail	Source	Description
Survey	Neighborhood	Istanbul Metropoliten Planlama (IMP)	Socio economic and demographic data per neighborhood per district, 2006
Spatial / vector	Metropolitan area	IMP	Isolines (5 meters) for European part of Istanbul
		IMP	Hydrographic network for European part of Istanbul
	Neighborhood	IMP	New administrative boundaries for Istanbul (after modification in 2008)
Census	Neighborhood	Turkish Statistical Institute (TUIK)	Household size per neighborhood per district, 2009
Meteorology	Florya station	Turkish State Meteorological Service	Maximum monthly precipitation (mm) 1975 - 2010
			Total monthly precipitation (mm) 1975 - 2010
			Average monthly temprature (°C) 1975 - 2010

3.4. Data inconsistencies

Data collected was not exempted from inconsistencies that reduce their quality. In the study area, there are administrative-boundary problems which are noticeable when district and neighborhood boundaries are overlaid: one neighborhood appears to be in two districts at the same time. It is important to mention that these administrative boundary inconsistencies were not further solved since it is a matter of an official Turkish institution.

Since the survey was based on a sample, data was crosschecked with official data from TUIK to identify how different values were from one database to the other. Based on the total population of 2007 from TUIK database, and a growth rate of 9.80 %o[3], total population of 2006 was estimated. The difference between the total

[3] The growth rate for 2007-2008 for Istanbul is 9.80%o. Therefore, it was assumed the same rate in order to estimate population of 2006.

population value obtained and the total population from household survey is of 1,276,251 inhabitants, which represents a 10% of total population, concluding the sample of the survey was representative.

Finally, applying questionnaires via a third person, in this case a translator, caused some loss of details that could be interesting for the analysis of the researcher. It was noted that translators did not write down everything that was being answered. Yet, information was used.

3.5. Data collection shortcomings

Any kind of social research based on survey questionnaires in Turkey requires special authorization from the Municipality. This issue arose once in Istanbul and an authorization from the Küçükçekmece district governorship (Kaymakamlığı'na) and from the local police department in Ikitelli neighborhood had to be obtained in order to avoid any problems that may happen. This was a very bureaucratic, logistic-demanding and time-consuming task which took a couple of days.

Local residents in Ikitelli Mehmet Akif and in Ikitelli Atatürk neighborhoods refused to cooperate with the households questionnaires arguing that they were busy or, sometimes, with a "no", which is a risk when using surveys. They expressed unconformity and distrust to people approaching to their houses, especially if this was not part of an official campaign like a census. Moreover, some women did not want to cooperate due to cultural reasons: their husbands were not at home. As a consequence, the questionnaire had to be adjusted together with the target population in order to continue with primary data collection and avoid the waste of more time.

The number of interviews and the way of developing them (see Section 3.3) were limited due to local people's cooperation, time and human resources (number of translators). Because of this data collection inconvenient, extra information from socio economic secondary data had to be collected to fill in the gaps of the primary data collection. For instance, it would have not made sense to ask shop owners or people in the street the number and age of people living the household since the household was not the level of detail of the study anymore. Therefore, this information had to be collected from the household survey.

3.6. Data analysis

Answers from the questionnaire were organized in an Excel spreadsheet. Next, answers for each question were quantified in order to see if there were repeated ones, and which one was the more frequent. For opened questions, answers were clustered according to their similarity. For example, to the question regarding the reason why this area is vulnerable to flash floods, answers related to distance to the river were gouped even though the exact answer was not “distance to the river” but “close to the river”, “area near the river”.

3.7. GIS analysis

GIS analysis included all the steps prior to the SMCE. In ArcGIS, a DEM was generated based on the 5 meters –isolines shapefile collected from IMP. Using the Feature to Raster tool, the isolines were transformed into a raster dataset with a cell size of 5 meters giving more information about the variations in height within the study area. The DEM served as input for creating the slope raster dataset of the study area using the Spatial Analysis tool, with the same spatial resolution.

The river network within the study area was used as input in order to create buffer zones to determine the different distances to river streams, considered as another important parameter to be included in the vulnerability assessment (see Section 5.2.2). Since the buffer is created as a shapefile, it was later transformed into a raster dataset with 5 meters spatial resolution.

In order to spatially display socio economic and demographic data at the neighborhood level , this information had to be incorporated in the attribute table of the administrative boundaries shapefile from IMP. Since the case study area comprises only two neighborhoods, the attribute table was editted, and data from the IMP survey questionnaire were directly added.

3.8. Spatial multi criteria evaluation (SMCE)

MCE is used when there is the need to reach a goal by combining different criteria in a structured way (see Section 2.3.4). Here, the specific goal is to assess urban vulnerability based on physical and socio economic criteria. MCE is theoretically based on the Analytical Hierarchical Process (AHP) developed by Saaty (1980) in which a problem with an overall goal is seen as a hierarchy composed of different levels (van Westen, 2009). The MCE was performed in a spatial way using the SMCE application in Integrated Land and Water Information System (ILWIS) software because of its user friendly interface, and its guiding assistance during the entire process.

The different primary and secondary quantitative information were transformed into raster datasets using ArcGIS. Next, they were imported into ILWIS format in order to proceed with the SMCE application which consisted on three main steps.

3.8.1. Criteria tree building

A "criteria tree" was developed in order to organize all the parameters in a structured way, establishing how the final and intermediate outputs will be calculated based on the raster inputs (Figure 9-3 in Appendix A). Parameters were organized according to the urban flash floods under climate change conditions vulnerability framework (see Section 4.3).

3.8.2. Standardization of criteria values

Since the criteria had different units, a standardization of the values in each criterion was done in order to have values within a range of 0 (not vulnerable) and 1 (vulnerable) and to combine the different datasets. Standardization was done using the "Rank order" method already included in ILWIS software, in which the values are placed in order of decreasing importance to vulnerability. This means that values that influence more in the vulnerability condition of the area will be in first places than those whose influence is less. Standardization was based on existing scientific literature about them, and will be explained in section 5.2.

3.8.3. Weighting of criteria

In this step, the relative importance of criteria to vulnerability within groups and among groups was assigned using the "Rank order" method provided by the SMCE application (ITC, 2005) from the lowest to the highest level in hierarchy (Peters Guarin et al., 2008). For instance, the relative importance of slope, distance to river streams, and altitude had to be determined in first place in order to estimate the weight of the "physical conditions" component, in an upper level, in comparison with "natural disasters" and "climate variability" components. Once these weights have been determined, one can proceed to the next upper level in which "exposure", "sensitivity" and "adaptive capacity" are placed. It is important to mention that the sum of the weights will always be 1. The same procedure was followed with the remaining criteria selected for the assessment.

3.8.4. Vulnerability index calculation

Finally, the vulnerability index was calculated according to figure 3-5. Since all the parameters involved in the procedure were raster layers, for every criterion, cell values were multiplied by their respective weights. Then, for the intermediate levels, the particular criteria corresponding to that sub goal were combined.

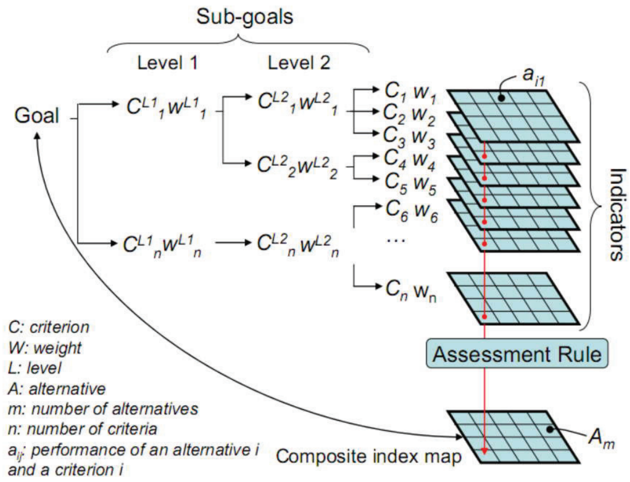

Figure 3-5 Procedure for SMCE
(van Westen, 2009)

It is important to mention that in this research, three intermediate outputs were generated: exposure, sensitivity, and adaptive capacity. The final vulnerability index was calculated by multiplying the exposure, sensitivity and adaptive capacity outputs by their respective assigned weights.

4. Urban flash floods under climate change conditions vulnerability framework and developing approach

This chapter describes the urban flash floods under climate change conditions vulnerability framework and approach developed for this research. The need for its design, the contribution from local knowledge to it and its structure will be described in detail.

4.1. General characteristics

This framework has been developed because there is concern on the impacts that the increase in frequency of flash floods due to climate change will have in the urban region of Istanbul (see Section 1.2). Furthermore, it responds to the need to develop a more inclusive approach based on knowledge from local people who have dealt with flash flood consequences. This framework borrows concepts from previous vulnerability frameworks (Turner et al., 2003, IPCC, 2007c, Polsky et al., 2007, Vincent, 2007, Hahn et al., 2009, Wilhelmi and Hayden, 2010) but also incorporates elements from local knowledge collected in the study area during fieldwork in the form of proxy indicators.

Three characteristics are highlighted here. First, this framework is compatible with participatory approaches, meaning that participatory tools in which local knowledge is prioritized can be used to obtain the necessary information for the assessment. Second, it can be updated depending on the particular context of the study area. If there is the need to increase or reduce the number of measures or components, then it can be done. Finally, it considers adaptive capacity as a modifying dimension. Therefore, actions have a direct feedback effect towards the vulnerability condition at the local level.

4.2. From local knowledge to vulnerability indicators

4.2.1. Local knowledge

Local knowledge has allowed an understanding of how people perceive vulnerability in the study area, and the construction of indicators to be included in the vulnerability framework. As general context, from the 30 inhabitants in Ikitelli Mehmet Akif and Ikitelli Atatürk neighborhoods who were interviewed, 25 were males (83.3%) and 5 were females (16.6%)[4]; and the average of time living/working in these neighborhoods is 15.3 and 15 years, respectively. In the next paragraphs local knowledge and how this was transformed into proxy indicators of vulnerability will be analyzed and commented.

4.2.1.1. Vulnerability to flood perception

The first question asked was whether people considered that their neighborhood was vulnerable to flash floods and why (see question 1.2 in Appendix B). This open question was posed in order to know if they were aware of the fact that they can suffer from flooding. 21 interviewees (70%) considered that the neighborhood where they live *is* vulnerable to floods, and the reasons that support this affirmation are shown in Figure 4-1. Here, 12 people (57% of those who affirm the neighborhood's vulnerability) related it to the presence of river, either considering the distance or other characteristic such as a narrow stream bed or strong water flow. Distance to the river was the most frequent reason not only referring to Ayamama river itself but also to the river stream that divides both neighborhoods (Figure 9-2 in Appendix A), because for them it is evident that areas closer to it are more likely to be flooded than areas farther away.

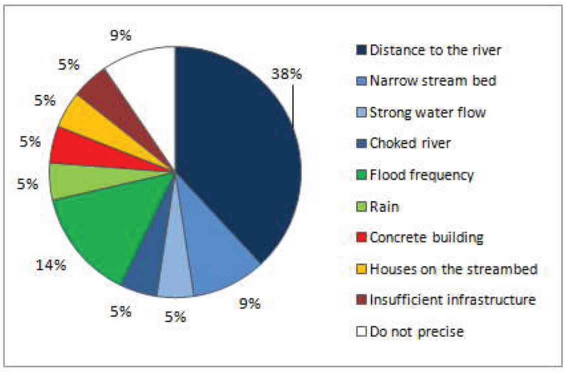

Figure 4-1 Reasons for considering Ikitelli Mehmet Akif and Ikitelli Atatürk vulnerable to flash floods

The remaining reasons have less importance to local inhabitants because they were mentioned just once. However, it is important to state that one interviewee was aware that the building of concrete walls along the river, instead of having a positive

[4] The fact that more men were reached is due to cultural reasons and does not mean that in the area male population is higher than female. Women in a Muslim environment such as in Istanbul are very difficult to approach to, especially if the researcher and translator are men.

effect, it had a negative one because this reduced the absorption capacity of soil. Therefore, flood is more prone to occur. This vulnerability condition was also agreed by the governor of Ikitelli Mehmet Akif; nevertheless, he considered that the main reasons for this were the narrow stream bed and the fact that people throw garbage to it, which in the end tend to block the flow of water.

Those 9 interviewees (30%) who considered that the neighborhoods were not vulnerable based it on the development of new infrastructure such as a canal and walls along the river. Since there are walls, water can flow within the space provided and not overspill.

4.2.1.2. Flood consequences based on the event in 2009

In order to know what the consequences of flash floods in the area were, interviewees were requiered to mention the most negative consequences of the flood event during 2009 (see question 1.3 in Appendix B). People perceive different negative consequences (Figure 9-4 in Appendix A); however, the one that most people recall (30%) is the presence of water in basements and in the fisrt levels of the houses. This was directly produced because of the accumulation of water in the entrance stairs and basements. Moreover, the saturation of the underground drainage system contributes to flood the basements and to affect the street network since it is very difficult to walk and drive[5]. Damaged houses constituted the second most frequent answer. It could have been that respondents who mentioned this idea meant the presence of water in the first levels of houses, but they did not precise the kind of damage. Injured and death people certainly was one of the consequences but not in these neighborhooods.

In order to know who people attributed the responsibility of the consequences of the flood events in 2009 (see question 1.4 in Appendix B), a set of six options were given: weather (rain), government (Municipality), other institutions, inhabitants, distance to the river, and others. Near half of the interviewees considered that the government was responsible for the consequences because they gave authorization for building in what they call “wrong areas” meaning close to the river[6]. For them, it is also responsibility of local government all the improvements that should be done along the river in order to avoid floods. 13 inhabitants chose “distance to river”

[5] This could be observed in a lower level on a very rainy day during fieldwork.

[6] This information coincides to what ARK TERA (2009) and Ozcan and Musaoglu (2010) have expressed about the amendment in urban plans in 1997 which turned this space into a residential area.

because they think that this is the principal factor why most of the infrastructure (houses) near the river stream were affected.

4.2.1.3. Importance of preparation campaigns

Preparation campaigns are important because they help increase awareness and prepare people in case of a flood event. Interviewed people were asked whether there had been flood preparation campaigns organized by institutions, and if they considered them as important (see questions 1.5.1 and 1.5.2 in Appendix B, respectively). To the first question, 28 out of 30 people agreed that neither Municipality nor any other institution organized preparation campaings prior to the flood in 2009, and this could be one reason why they considered Municipality as responsible, even though it was not explictly mentioned. When information was cross checked with the governor of Ikitelli Atatürk neighborhood (see question 1.4.1 in Appendix C), he mentioned that there were flood preparation activities organized by Yldiz Technical University, together with Küçükçekmece district and Istanbul Metropolitan Municipality. Here, technical works were developed as well as first-aid campaigns after the event but did not clarify whether there had been campaigns before.

Interviewees in the study area recognize the importance of these types of campaigns despite the fact that they were not organized. From the 25 people (83%) who considered these campaigns as important, 8 think so because they help increase knowledge and awareness among population about what to do in case of flooding. This is also related to people's safety because the more knoweledge they have about what to do, the more prepared and less affected they will be. For instance, interviewee nº5 thinks that if these campaigns were organized, "places located on the river areas can be evacuated", indicating that residents in those areas would know how, when and where to evacuate. Interviewed people also think that these preparation campaigns are useful for people's safety such as avoiding injuries or deaths, which happened last year.

4.2.1.4. Knowledge about climate change

Climate change is a complex topic because it incorporates many concepts such as climate, variability, climate patterns; etcetera which may sound difficult or even strange for many common people but the term is becoming more popular since it is mentioned in news or on television. In the study area, there was the need to know what people understood by climate change (see question 1.6 in Appendix B) as part of the access to information to see whether they associate this issue to the occurrence of flash floods like the one in 2009.

As a general conclusion, knowledge about climate change is weak. Climate change is most commonly associated to "seasonal changes" (Figure 9-5 in Appendix A) meaning that the changes between seasons are different now in terms that they start later. They also relate it to weather conditions since they answered "cold-hot", "rain-snow", "it's raining; now it is not". This lack of knowledge may be explained by the education level of local inhabitants since, in general terms, less than 50% assisted to middle, high and superior education centers. This lack of a clear knowledge about climate change and how it influences the frequency of occurrence of flash floods in the area is related to the actions that they could do in order to reduce the consequences of floods.

4.2.1.5. Ocurrence of flood events in the past and in the future

People were asked the number of flood events in a time span of 20 years (see question 1.10 in Appendix B) in order to see how present flood events are in their memories, and to estimate the number of events that have occurred in this area. The range of answers was wide because some interviewed people mentioned that there had been 10 or even 15 flood events in Ikitelli Mehmet Akif, while others just 2 or 3 events. These last numbers are more coherent when compared to official records (see Section 2.1); furthermore, both governors indicated that there had been 2 and 3 flood events. Then, it is important to consider that for this kind of question people tend to exaggerate a bit and it should be cross checked.

Perception about whether the occurrence of floods will increase or decrease in the future and the reason of it (see question 1.7 in Appendix B) was also of interest. More than half of the interviewees perceived that flash flood events like last year will increase. There are three main reasons for this increase: "because news or weather forecasts say so", "construction is increasing", and "we do not take precautions". The first reason is not properly a reason and indicates that those respondents in fact did not know why flash floods will increase. The second one indicates that those respondents could establish a relationship between urbanization and the increase in the frequency of flash floods, although they did not explain further this idea. The last one is more associated to the consequences of flood events than to the increase in frequency itself.

For 6 interviewees (20%), the possible increase or decrease of flash flood events is not that important since they answered with "God knows", meaning that only God knew whether rain, and therefore flood events would be more frequent or not. This presence of religious belief in some answers plays a role in their vulnerability because it is related to little interest in a possible future increase in precipitation and flash flood events. This religious characteristic observed would not have to interfere at all with the vulnerability condition; however, when combined with low levels of education, it becomes a problem since it makes inhabitants less aware.

4.2.1.6. Coping capacity

What people would do to reduce the consequences of floods (see question 1.8 in Appendix B) depends on how much knowledge they have about vulnerability to flash floods or on what they see as the main problem. Answers obtained were varied; however, the most frequent action that was mentioned was to "close the top of the river" because it would avoid the spill of the flow of water during a heavy rainfall period, as well as the presence of garbage in the river bed that blocks the flow of water. People also think that widening the streambed because more water could flow, removing houses near the river because less houses would be flooded, and building infrastructure such as walls along the river, will reduce the consequences of floods. These and other actions (Figure 9-6 in Appendix A) are considered as short – term period actions. They recognize as the main problem the river and the distance to it which constitues the reason why they think these neighborhoods are vulnerable. These actions *do* help but it is also important to address the problem of vulnerability in long-terms by creating consciousness and organizing people.

Finally, to have people organized in local organizations and/or comittees in order to reduce impacts of flash floods (see question 1.9 in Appendix B) is something that not only 24 out of 30 interviewees but also both governors recognized as important. They argued that people are more efficient in groups than alone in case of an emergency such as in 2009, when they got organized and distributed food and other aid. Moreover, they think that organizations increase people's awareness since they can exchange experiences and knowledge between them.

4.2.2. Indicators from local knowledge

This local knowledge gave important hints about what should be considered in a vulnerability assessment. The survey questionnaire included opened and closed questions. Answers to opened questions were more varied and helped understand what other factors influence vulnerability. Due to this variety, answers were clustered according to their similarity; however, answers to closed questions did not have to be clustered since the options were given a priori. Then, answers for every question were quantified to see which one was the most frequent, therefore, the most representative to local inhabitants, and the following indicators could be constructed.

From the answers, the first indicator built is *distance to the river stream*, which is a proxy physical indicator of exposure; therefore, it should be incorporated in the exposure dimension. For inhabitants, this indicator is considered to be the most important factor that determines the physical vulnerability to floods not only in the case study area: Ikitelli Mehmet Akif and Ikitelli Atatürk neighborhoods but also in the entire Ayamama river basin since areas closer to the river stream were more affected than others during the flood event in 2009. This indicator is measured in metric units; however, it is not thought to be obtained directly from local people since the information they might provide is not as accurate as the one that can be obtained from secondary sources such as GIS layers. The object of interest is to have a spatial representation of how far households are to the river streams.

Number of damaged houses with the first levels flooded was the next indicator built since this was the most evident and common consequence in 2009 based on local knowledge, and it is a proxy indicator of the magnitude of a flash flood event. The flooding of the first levels is produced due to the overflow of the river and also due to the accumulation of water from precipitation in the entrance (see Section 4.2.1.2) influenced by the style of buildings, since almost all of them have exposed basements. This indicator is measured by the "number of", should be placed in the exposure dimension, and data can be directly obtained through participatory tools such as survey questionnaires and/or focus group discussions. This would allow local people to provide extra details such as the kind of damages or damage costs, obtaining extra qualitative information for the assessment (Sagala, 2006).

The *number of flash flood events* registered in a period of time is an indicator of their frequency. It is recommended that local people *do* contribute to give this information because it is a good exercise to remember past hazard events and what they did to cope with them. Ford and Smit (2004), and Ford et al. (2006) suggest that based on these previous experiences, present and future exposure conditions can be estimated. The period of time considered for the assessment has been the last 20 years; however it is susceptible of change depending on the research purposes and data availability

Knowledge about climate change is another importatn indicator of how much people know about this issue due to access to information, and it should be placed in the adaptive capacity dimension. Instead of beign measured in a quantitative way like the other indicators discussed, it should be measured in a nominal way with three classes: poor knowledge, average knowledge, good knowledge. This categorization is based on whether they identify climate change as a process or just the transition between seasons, see the relationship between climate change and an increase in flash floods or not, and variations in weather conditions such as precipitation or temperature. This indicator is to be measured at the household level by the use of survey questionnaires through interviews.

Organized preparation campaigns have been recognized by people as a mean to increase awareness and to be more prepared to cope with flash floods (see Section 4.2.1.3). Since these campaigns should be organized by official institutions, *the number of organized preparation campaigns* is an indicator of how much these institutions, especially the local government, are involved with local inhabitants, and should be placed in the adaptive capacity dimension. This indicator is measured by "number of", data is obtained directly from local knowledge, and a minimum of one campaign is considered to favour adaptive capacity. However, a maximum number has not been established. It is recommended that the information given by people be cross checked with other local actors such as the Municipality because it may happen that inhabitants, due to lack of information, respond that there were not preparation campaigns when they really were.

Related to the indicator explained above, the *number of people participating in preparation campaigns* is an indicator of awareness derived from local knowledge because in these campaigns they can learn about flash flood events and how to cope with their consequences. Therefore, people would be more aware of their vulnerability condition. This indicator is to be developed at the household level or at the neighborhood level, where knowing a number of these participants is representative. At a district or province level, this indicator should be adapted.

Finally, the last indicator built from local knowledge is *participation in local organizations,* which reflects interaction between neighbors. To participate in these local groups not only contributes to increase awareness but also to strengthen cooperation between neighbors, increase their adaptive capacity and be less vulnerable to flash floods. This indicator is again to be developed at the household level or at the neighborhood level, and it is measured by the "number of" people participating in such organizations.

All the indicators from local knowledge were incorporated in the urban flash floods under climate change conditions vulnerability framework under different dimensions and components. In the next section, the complete structure of the framework will be explained, including and making explicit which other indicators were borrowed from existing literature.

4.3. Framework for vulnerability assessment

The general structure of the framework (Figure 4-2) considers in first place a set of externalities (Wilhelmi and Hayden, 2010). On the one hand, migration to the Istanbul area in the last decades has influenced urban expansion because there has been a need to build more houses and infrastructure to support new inhabitants (Maktav and Erbek, 2005). On the other hand, climate change influences precipitation patterns and the frequency and magnitude of flash floods is expected to increase, especially in urban areas (see Section 2.1). The above mentioned externalities affect the measures of the framework. For instance, migration to urban areas increases the number of inhabitants, and household size is modified. There is a development of new urban infrastructure that is done regardless the condition of natural corridors that some areas have (Ozcan and Musaoglu, 2010). Houses and factories are built in areas which might not be suitable for residential and industrial purposes because they are located in a flood prone area within Ayamama river basin. The distance of infrastructure to main rivers streams is then reduced and the likelihood to be flooded is higher.

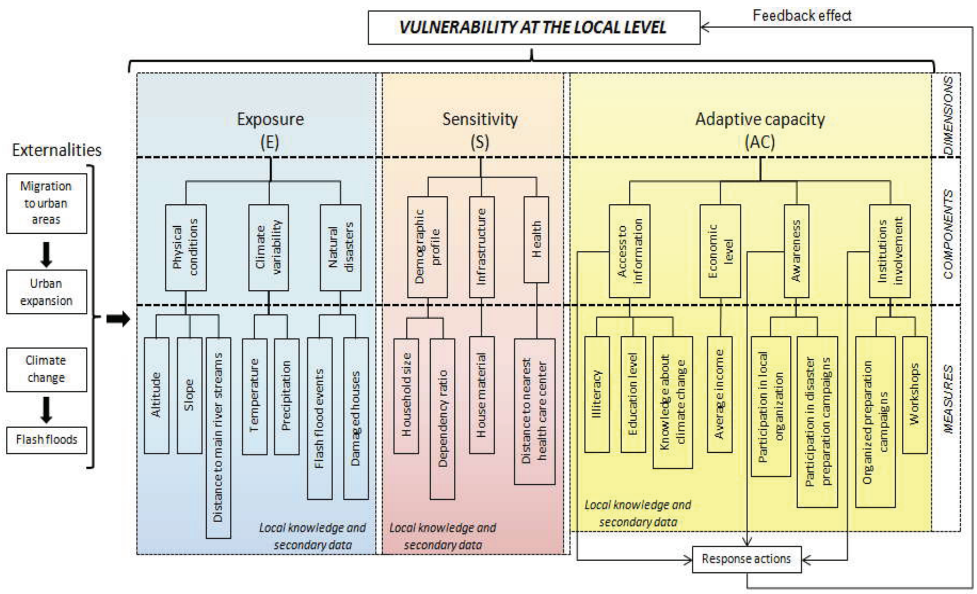

Figure 4-2 Urban flash floods under climate change conditions vulnerability framework

The framework presents a three-level structure like in the VSD: dimensions, components, and measures because it is a didactic way to present and indicate that measures are part of components and these are part of dimensions. Measures constitute the concrete indicators that will allow the quantification of each component, and components are the main characteristics of each dimension. This kind of structure allows a comparison between vulnerability assessments in different areas (Polsky et al., 2007).

While the dimensions are represented by exposure, sensitivity and adaptive capacity according to what the IPCC (2007c) proposes, the components include four characteristics proposed in the LVI: climate variability, natural disasters, demographic profile, infrastructure, and health (Hahn et al., 2009). The remaining physical conditions, access to information, economic level, institutions involvement, and awareness have been included due to their relevance for assessing vulnerability at the local level and their absence in previous frameworks as such. In the next paragraphs, the three dimensions –each one with their components and measures- will be explained in detail.

4.3.1. Exposure

Exposure is related to the frequency and magnitude of flash floods as a climate-related hazard (see Section 2.2); and, for a vulnerability assessment, exposure has to include a set of parameters that describe or influence these characteristics. Based on this, this framework considers that an area is more or less exposed to a flash flood event depending on physical conditions that encloses three measures: altitude and slope, taken from existing literature; and distance to the main river streams which comes from local knowledge.

Altitude represents exposure since lower areas are more prone to suffer from flooding than higher areas. Ikitelli Mehmet Akif and Ikitelli Atatürk are located between 30 and 95 m.a.s.l, and the most flooded areas during 2009 were those between 30 and 60 meters. Slope is included because it determines areas in which water might be either retained or may flow due to flatness or steepness of the surface, respectively. Finally, areas closer to river streams are more affected due to overflow. All these parameters are obtained not from local knowledge but from secondary sources.

Since flash floods are produced mainly by the amount of rainfall on a short time span (see Section 2.1), it is important that this framework consider climate variability as one of its components. Climate variability addresses the influence of the changes in the climate expressed in temperature and precipitation in the area. Some ways of analyzing climate variability and incorporating it into a vulnerability framework have been developed using global climate models (GCM) and downscaling them for specific regions (Zhang, 2005, Fujihara et al., 2008). These models represent actual conditions in precipitation and other parameters in the atmosphere, and make possible the simulation of global climate response (IPCC, 2009).

Even though these models exist and may provide good results, they are too complex for the specific purposes of this vulnerability assessment which is to assess vulnerability with the participation of local people. That is the reason why it has been chosen to analyze 30 years –climate data according to Hahn et al. (2009): considering the standard deviation of the total monthly precipitation and temperature values obtained from a gauge station located in the study area. It is recommended that climate data be no less than 30 years so that a tendency can be established.

The last component within the exposure dimension is constituted by "natural disasters" which addresses two measures: the first one is, in this particular case, the number of flood events registered in a period of time, brought from local knowledge. The second measure is constituted by the number of houses affected and was incorporated because it reveals the magnitude of the flash flood event (see Section 4.2.2).

4.3.2. Sensitivity

Sensitivity groups certain characteristics that make a society more prone to suffer from being exposed to flash flood events due to climate change (see Section 2.2). These characteristics have been incorporated into the framework in the form of three components: demographic profile, infrastructure, and health. For instance, an area with very young or very old population will be more sensitive to flash flood events because they depend more on the rest of inhabitants: children and elderly cannot protect themselves so easily and need assistance from older and younger people, respectively. That is why it is important to identify a dependency ratio in order to see the relationship between the population under 15 plus over 65 years old, and the population between 19 and 64 years old (Hahn et al., 2009). The higher the dependency ratio, the higher sensitivity there is.

Household size has also been included as a demographic profile measure, from previous literature, because it is an indicator of the number of people living in a household (Haki et al., 2004) which can lead to knowing the distribution of people affected in case of a flash flood event. By asking how many people live in a household, an average for the neighborhood can be estimated. The larger the household size, the more sensitivity there is since the same quantity of resources such as income or food has to be shared between more people.

Health issues also influence how sensitive a society is since sick population and/or population who usually get sick are more likely to need some assistance and are more vulnerable to suffer during flash floods. It is important to know if these people have the required facilities to be assisted in their neighborhoods. That is why the "health" component is measured by the average distance in time by vehicle to the nearest health center, an indicator borrowed from Hahn et al. (2009). Average time was chosen to be the unit since it is easier to for people to calculate it in that way. No specification of the characteristic of health centers has been made since some places do not have hospitals or clinics but they have minor health offices. In this sense, any of them can be considered.

Finally, infrastructure also influences the sensitivity dimension of vulnerability at the local level. House material, borrowed from Wigati (2008) is the only measure considered in the framework, and it is related to the number of damaged houses as well as the socioeconomic status of the owner. Worse materials are less resistant than better materials when flooded and indicate low socioeconomic status, which increases sensitivity.

4.3.3. Adaptive capacity

This framework focuses on the societal aspect represented by adaptive capacity. Therefore, it constitutes a doubly important dimension that combines social, economic and institutional components. The first component that was considered is "economic level" which is measured by monthly average income, borrowed from Haki et al. (2004). What an inhabitant earns determines his/her acquisition power and it serves as input to conduct practical actions to modify vulnerability and to cope with flash flood consequences. For example, in an area in which the average income is higher, there exists more money available that could be eventually invested in preparation actions in case of flood events such as building concrete barriers to avoid flooding. Moreover, average income is also related to house materials in the sensitivity dimension since a better salary allows the use of better house materials which reduces the sensitivity to flash flood events. Average income can be directly obtained from local inhabitants by surveys but also from census data. By knowing the average income per household once can estimate the average income per neighborhood.

One of the numerous purposes of vulnerability assessments to climate change (see Section 2.3) is to increase awareness of climate change impacts among population (Hinkel, 2011). Thus, it is important to include in the framework a component devoted to awareness. At the local level, associations formed by neighbors strengthen mutual cooperation and organization, and they constitute a platform in which exchange of ideas and dialogue about issues that concern the neighborhood is fomented. For that reason, the number of people participating in local organizations, built from local knowledge, has been considered as a measure of awareness.

Disaster preparation campaigns (see Section 4.2.2), included as measure, and should be organized by state official institutions in order to prepare people for a disaster event. They are usually developed considering an education component which will make inhabitants conscious and more aware about their vulnerability condition. Therefore, more people participating in these campaigns increase the awareness and their adaptive capacity to cope with flash floods.

Access to information is measured by education level, illiteracy and knowledge about climate change. Education level has been used in other studies (Haki et al., 2004) and is analyzed by the percentage of people in the neighborhood who attended primary, middle-high school, and superior education. The more percentage of people who attended higher levels of education, the more capacity there is to cope with flood consequences, and less vulnerability there is. Illiteracy, also used by Haki et al. (2004) indicates whether people older than 6 years know how to read and write since it is assumed that younger ones are still learning. Then the percentage of illiterate inhabitants per neighborhood can be estimated.

Within a vulnerability to climate change framework, it is necessary to consider specific knowledge related to the issue of climate change (see Section 4.2.2). This will indicate whether people can associate flash flood events to changes in climate variability or not. It is important not to limit only to literacy and education level since there may be cases in which people attended only elementary school but are well aware of climate change and its impacts because of a personal interest in the topic. People are requested to answer what they know about climate change and their answers analyzed. Laukkonen et al. (2009) consider that this knowledge about climate change is important because it is the base of the adaptive responses that people might develop with support from local authorities.

Local government also plays a role in vulnerability. Vincent (2007) states that no adaptation actions are exempted to occur without an institutional framework since this context allows people the access to those adaptation opportunities. Therefore, this framework includes the involvement of institutions that is measured by the number of preparation campaigns as well as the number of organized workshops. The first one is understood as trainings in which people are told the main evacuation routes or security points or how to deal during a flood event. The second measure is composed by workshops in which people are taught about the impact of flash floods. These can be under a project or a local program from the local or regional government. Both of them have the potential to create hazard and climate change consciousness and to develop strategies to adapt to flash flood events. The information needed is the number of preparation campaigns and workshops organized. Not only people are asked about but also the governors since they work in the local government.

Finally, within the adaptive capacity dimension, it is access to information, awareness, and involvement of institutions the measures that set the conditions for developing response actions. These actions have direct effect towards vulnerability and can be positive: by reducing vulnerability, or negative: by maintaining or increasing it.

4.4. Assessment approach

The application of a framework in order to assess vulnerability supposes certain ways of doing so such as a main focus, tools to use, analytical methods, among others. Luers (2005) considers that putting a vulnerability framework into a real situation is a difficult task, sometimes with not good results because when assessment results are used by policy-makers, the help they get to prioritize areas is limited. This limitation might be due to deficiencies in the methods chosen to obtain information for the analysis or in the analysis itself. Therefore, it is important to consider the approach by which the framework will be developed.

The urban flash floods under climate change conditions vulnerability framework is placed within the boundaries of the start-point, social and bottom-up approaches discussed previously. It seeks to identify reasons and the spatial distribution of vulnerability so it can be modified through a feedback effect. Although it focuses more in the social aspect of vulnerability, this framework is “non-exclusive” in terms that it does not reject physical aspects, but includes them as part of the vulnerability conceptualization. It pays special attention to adaptive capacity since the framework considers it is directly related to determining vulnerability. The dynamic condition of vulnerability makes it subject of change if modifications in any of their components occur (Luers, 2005). In this framework, the arrows pointing to “response actions” plus the thicker arrow that ends in “vulnerability at the local level” highlight this characteristic.

The approach suggested to develop this framework is based on the use of local knowledge from local inhabitants which is reached through participatory methods (see Section 2.3.5) because their participation, excluded in previous assessments, is needed. Survey questionnaires are the main instrument to get information, but it is also recommended the use of focus group discussion in which different actors (not only local people) are involved. These groups facilitate the actors to realize who else is involved in this vulnerability situation, and also to compile, organize and crosscheck this local knowledge. This last activity is important because it not only increases the quality of local knowledge for the purpose of the vulnerability assessment but also has teaching purposes for the inhabitants since they learn from other participants. In an ideal situation, actors or stakeholders participate in group meetings and discuss, with the help of a moderator, different points regarding urban vulnerability related to flash floods due to climate change starting with the framework in use.

Although there is a strong interest in developing the framework in a participatory approach, it recognizes that some data cannot be obtained from local knowledge since it is too specific and precise. That is the case of climate variability and physical conditions: precipitation and temperature time series as well as altitude, slope and distance to river streams need to be obtained from a secondary source such as official meteorological stations, and GIS layers. The framework then combines both qualitative and quantitative secondary data into the assessment. Finally, applying this vulnerability framework in the chosen study area has had interesting results that will be presented and explained in the next chapter.

5. Application of framework in Ikitelli Mehmet Akif and Ikitelli Atatürk, Istanbul

This chapter presents the application of the framework in the study area. It explains the measures involved in the vulnerability assessment through SMCE, and the results of the overall assessment.

5.1. Defining the measures

The urban flash floods under climate change conditions vulnerability framework presents all the elements needed for assessing vulnerability in a specific area (see Section 4.3). However, during fieldwork not all of the elements from the framework could be collected (see Section 3.3 and Section 3.5). Table 5-1 shows the parameters that were obtained, transformed into raster layers, and incorporated into the SMCE.

Table 5-1 Parameters involved in the vulnerability assessment

Dimension	Component	Measure
Exposure	Physical conditions	Slope
		Distance to river streams
		Altitude
	Natural disasters	Flash flood events
	Climate variability	Precipitation average standard deviation 1975-2010
		Temperature average standard deviation 1975-2010
Sensitivity	Dempgraphic profile	Dependency ratio of 0-14 and older than 65 years old between 15-64 years old (percentage)
		Household size
Adaptive capacity	Access to information	Education level
		Iliteracy older 6 years (percentage)
	Economic level	Average income

5.2. Standardizing the measures

An explanation regarding how the measures available were standardized for the vulnerability assessment will be explained in the coming sections. The first three measures (slope, distance to river streams, altitude) included continuous data and went through a more complex standardization process.

The remaining measures (flash flood events, precipitation and temperature average) including socio economic measures, presented data registered at the neighborhood level. Since the case study area is composed of only two neighborhoods: Ikitelli Mehmet Akif and Ikitelli Atatürk, each raster dataset included only two values, one per each of the neighborhoods, which needed to be standardized. In this case, two ranking orders were assigned, depending on which value was higher (ranking 1) and lower (ranking 2), even though there was not much difference between them. When standardized, the first ranked order got a value closer to 1, whereas the second ranked order a value closer to 0.

5.2.1. Slope

Slope in the study area ranks from 0 to 19 degrees. The raster layer was re classified and new classes were ranked based on a previous vulnerability assessment for the middle and lower parts of Ayamama river basin developed by Ozcan and Musaoglu (2010). Table 5-2 shows that lower slope values have a higher importance in order to determine vulnerability due to the flatness of the terrain.

Table 5-2 Slope classes and ranking order

(adapted from Ozcan and Musaoglu, 2010)

Class (°)	Ranking order
0	1
0-5	2
5 a 10	3
>10	4

5.2.2. Distance to river streams

It is a fact that areas closer to river streams are more affected due to overflow. Based on Fernández and Lutz (2010), the study area was re classified into 100 meters spaces from the river streams. Table 5-3 indicates that areas within 100 meters from the river streams are more prone to be flooded; therefore, have a higher ranking order than areas located 300 meters away from them. This class, together with more than 400 m., has been placed in the same ranking because they influence in the same level to vulnerability conditions.

Table 5-3 Distance to river streams classes and ranking order
(adapted from Fernández and Lutz, 2010)

Class (m)	Ranking order
0-100	1
100-200	2
200-300	3
300-400	4
> 400	4

5.2.3. Altitude

The study area ranges between 30 and 95 m.a.s.l. Here, the most affected infrastructure during the events in 2009 was located between 30 and 60 m.a.s.l. Based on this information, on the assessment developed by Ozcan and Musaoglu (2010) and on the fact that the elevation data had a spatial resolution of 5 meters, altitude was classified in groups of 10 m.a.s.l. Table 5-4 indicates the order of the different classes. Classes above 70 meters have the same importance and have been placed in the same order.

Table 5-4 Altitude classes and ranking order
(adapted from Ozcan and Musaoglu, 2010)

Class (m.a.s.l)	Ranking order
30-40	1
40-50	2
50-60	3
60-70	4
70-80	5
80-90	5
90-95	5

5.2.4. Flash flood events

Data regarding the number of flash flood events was obtained at the neighborhood level. This means that only two values were considered: 2 and 3 for Ikitelli Mehmet Akif and Ikitelli Atatürk, respectively (Table 5-5). When standardizing these values, 3 was assigned ranked as 1, and 2 ranked as 2.

Table 5-5 Flash flood events

Neighborhood	Number of flash flood events
Ikitelli Mehmet Akif	2
Ikitelli Atatürk	3

5.2.5. Precipitation and temperature average standard deviation

Average precipitation and temperature historic series from 1975-2010 from Florya Station within Ayamama river basin were considered. To incorporate the variability in the assessment, standard deviation was calculated (Table 5-6) according to Hahn et al. (2009). The same standard deviation value was used for both neighborhoods; therefore, they were standardized as 1.

Table 5-6 Precipitation and temperature average standard deviation

Neighborhood	Average standard deviation 1975-2010	
	Precipitation (mm)	Temperature (°C)
Ikitelli Mehmet Akif	43.18	7.03
Ikitelli Atatürk	43.18	7.03

5.2.6. Socio economic measures

Table 5-7 and Table 5-8 show the socio economic measures that were included in the sensitivity and adaptive capacity dimensions, respectively.

Table 5-7 Socio economic measures in the Sensitivity dimension

Neighborhood	Dependency ratio (%)	Household size
Ikitelli Mehmet Akif	43.82	4.47
Ikitelli Atatürk	47.12	4.75

Table 5-8 Socio economic measures in the Adaptive Capacity dimension

Neighborhood	Education level (% of population)			Illiteracy older than 6 years (% of population)	Average income
	Primary	Secondary	Superior		
Ikitelli Mehmet Akif	55.27	18.42	26.3	7.39	923.35
Ikitelli Atatürk	53.32	20.7	25.97	7.42	924.56

5.3. Weighting the measures, components and dimensions

Once all measures were ranked and standardized between 0 and 1 as explained in the sections above, they were weighted using the Rank order method. Within the "physical conditions" component, the criteria slope, distance to river streams, and altitude were weighted based on Fernández and Lutz (2010). On the one hand, distance to the river streams was considered as the measure to contribute more to flood vulnerability than the remaining two. Therefore, it was assigned ranking one. On the other hand, altitude and slope were considered to influence in the same proportion, and both of them were placed in ranking two. The weights were automatically calculated, giving a higher weight to distance to river streams and the same weight for the other two.

Precipitation and temperature average standard deviation 1975-2010, within the "climate variability" component, were ranked and weighted giving a higher weight to precipitation since it has a direct relationship to the occurrence of flash flood events in the area. Finally, in order to estimate the weight of the "exposure" dimension, physical conditions, natural disasters and climate variability components were ranked in that order because it was observed that it is the physical conditions the ones which determine the areas that will be more affected in a heavy precipitation and flood event.

Within "education level" measure, the percentage of population who attended primary, middle and high school, and superior education were weighted according to Haki et al. (2004). Here, the ranking order is as follows: primary, middle and high school, and superior education because the more people who attended primary school means less people who attended higher education. This is translated into low education level and contributes more to vulnerability than having more people who attended superior education.

In order to weight the "access to information" component in the immediate upper level, education level and illiteracy older than 6 years were compared. The latter measure was given a higher weight than education level (Haki et al., 2004) because people who do not know how to read or write have less accessibility to information regarding floods and climate change, and are more vulnerable than people who *do* know how to read and have at least some education. Then, access to information and economic level were ranked in the same level since both of them contribute in the same intensity to determine adaptive capacity.

Within the “demographic profile” component, dependency ratio and household size were ranked in first and second place; therefore, dependency ratio was given a higher weight based on the fact that age more people outside the working group means more people to take care of, influencing sensitivity more negatively than the number of people per household.

Finally, the next upper level considered the three dimensions: exposure, sensitivity and adaptive capacity. Within vulnerability to climate change, adaptive capacity contributes more to this condition (see Section 2.2); and that was the reason why it was given a higher weight value than the remaining two dimensions. Table 5-9 shows the final weights given to the different measures, components and dimensions.

Table 5-9 Weights for the measures, components and dimensions

Dimension	Component	Measure
Exposure (0.33)	Physical conditions (0.61)	Slope (0.19)
		Distance to river streams (0.61)
		Altitude (0.19)
	Natural disasters (0.11)	Flash flood events (1)
	Climate variability (0.28)	Precipitation average standard deviation 1975-2010 (0.75)
		Temperature average standard deviation 1975-2010 (0.25)
Sensitivity (0.17)	Dempgraphic profile (1)	Dependency ratio of 0-14 and older than 65 years old between 15-64 years old (percentage) (0.75)
		Household size (0.25)
Adaptive capacity (0.5)	Access to information (0.5)	Education level (0.25)
		Iliteracy older 6 years (percentage) (0.75)
	Economic level (0.5)	Average income (1)

5.4. Vulnerability assessment result

Vulnerability is explained as a relationship between three dimensions: exposure, sensitivity and adaptive capacity (see Section 4.3). The SMCE application allowed the estimation of each of the three dimensions for the study area according to how the different measures, components and dimensions were combined in the criteria tree (Figure 9-3 in Appendix A).

Exposure, as a combination of physical conditions, climate variability and natural disasters, is higher in the areas within 100 meters from the river stream that divides both neighborhoods, and on the eastern boundary of Ikitelli Mehmet Akif, here due to the Ayamama river. Areas located at a larger distance from the river streams and at higher altitude levels are less exposed to flash floods (Figure 5-1 a).

Sensitivity and adaptive capacity do not show much variation in the study area, which was something known beforehand, because they were based mainly on discreet census data at the neighborhood level (see Section 5.2.6). Sensitivity is the product of only one component: “demographic profile” and adaptive capacity of “access to information” and “economic level”. These neighborhoods are pretty homogeneous in socio economic terms. For instance, the percentage of illiterate people older than 6 years old in Ikitelli Mehmet Akif and Ikitelli Atatürk is 7.39 and 7.42%, respectively; and 53.32% of population attended primary school in Ikitelli Atatürk whereas 55.27% in Ikitelli Mehmet Akif. This means that sensitivity and adaptive capacity values are nearly the same (Figure 5-1 b, c).

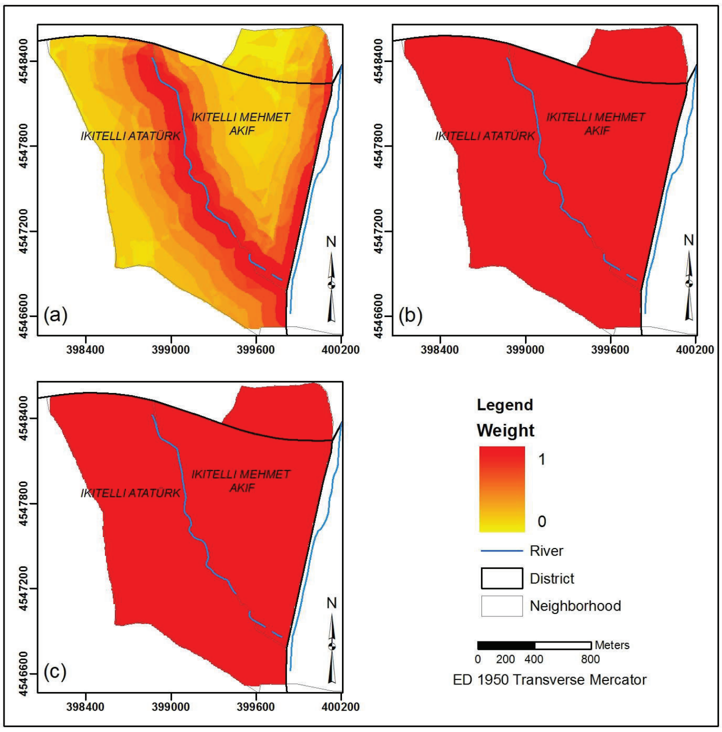

Figure 5-1 SMCE outputs: (a) Exposure, (b) Sensitivity, (c) Adaptive capacity

The outputs regarding exposure, sensitivity and adaptive capacity discussed above represented intermediate steps in the calculation of the vulnerability index which constituted the final goal in the SMCE application. Based on this, vulnerability in the study area is high, with values ranging between 0.79 and 1. It shows a similar pattern to exposure; therefore, the most vulnerable areas are those along the river stream that divides both neighborhoods (Figure 5-2). The central part of Ikitelli Mehmet Akif and the western part of Ikitelli Atatürk are less exposed because they are located between 60 and 70 meters high and more than 300 meters from the river stream.

The calculation of a vulnerability index is useful because it gives information to policy-makers about which areas are more vulnerable and where to focus attention. However, it has to be considered that this index is completely dependent on the parameters and on the way that they have been previously combined. To begin with, the vulnerability map confirms information from local knowledge regarding the reasons why the study area is vulnerable (see Section 4.2.1.1). According to local people, distance to the river streams was the main physical factor that influences vulnerability in these neighborhoods. However, adaptive capacity and sensitivity information is missed in the final map due to their unique values for one entire neighborhood, and the little socio economic heterogeneity that these neighborhoods present.

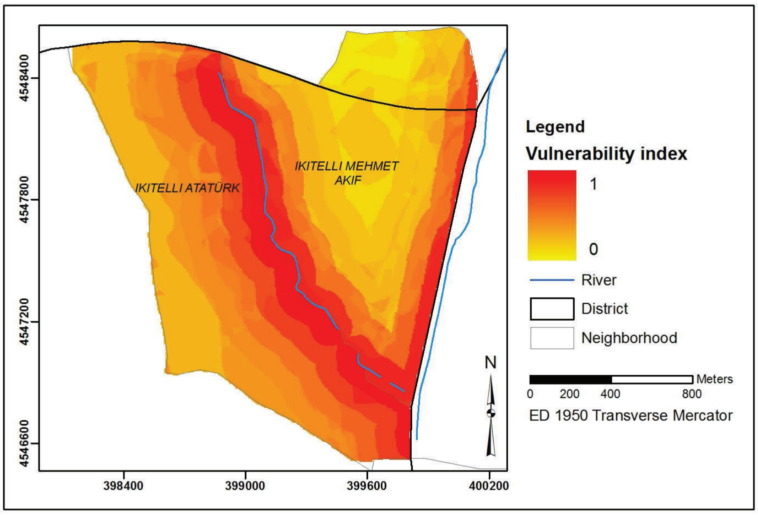

Figure 5-2 Vulnerability index map

6. Discussion

This chapter presents the discussion regarding local knowledge and its incorporation in a vulnerability assessment, the designed urban vulnerability framework, and its applicability in a particular context as well as considerations when applying it.

6.1. Local knowledge in an urban vulnerability assessment

One of the questions formulated at the beginning of this research was how can local knowledge be included in an assessment. Results show that local knowledge in Ikitelli Mehmet Akif and Ikitelli Atatürk was useful for comprehending the context regarding vulnerability. Local knowledge demonstrated that inhabitants of these two neighborhoods in Istanbul perceive vulnerability in a contradictory way. They recognize these neighborhoods as vulnerable because of two main reasons: first, the distance to the river streams, and second, the presence of 1.5 meter of water in basements and in the first level of the buildings seen during last year´s flood event. For them, vulnerability is explained merely by physical characteristics since they do not consider that social aspects such as education status, average income or participation in local organizations also contribute to their vulnerability status. However, when they are specifically asked about how important it is to be organized in case of a flash flood event, they recognize its importance. This indicates that somehow they are conscious that they need to increase their awareness towards flash flood events in order to be more prepared in the future. Policy-makers could use this information in order to ameliorate their preparation plans by focusing on this awareness “condition”.

Local knowledge can also be included in an assessment from the first steps which involve the framework building process. In this research, local knowledge constituted an important part in the building of the urban vulnerability framework. It helped define measures and components that were later included in the framework. Local knowledge has a considerable potential for vulnerability assessments. It has demonstrated to open new lines of work because new elements can be incorporated in order to understand vulnerability to climate change. For example, from literature and fieldwork experience, it was seen that neighborhoods are spaces characterized by a close relationship between neighbors since they know each other and share common places during their daily routines. At the local level, new components can be considered such as trust and reciprocity between neighbors because it influences their adaptive capacity (Pelling and High, 2005), and represent a good and immediate alternative of help during flood events. At the local level, these kinds of liaisons are stronger, faster, and have a better positive impact than actions from the local government.

Local knowledge can also be included in the assessment during the weighting of every parameter step involved in the SMCE. Previous work (Sheppard and Meitner, 2005, Peters Guarin et al., 2008) have succeeded in incorporating local knowledge and perception into the quantification of the importance of all the parameters that contribute to vulnerability. Nevertheless, participatory weighting was not developed in this case because of time and logistic issues. Once built the urban vulnerability framework, a group discussion with participants would have functioned as a platform for establishing these weights but this needed extra coordination and organization that was not available at that time.

Regarding what people perceive about two important issues of this research: flash floods and climate change, inhabitants perceive that flash flood events will increase; however, a proper reason for this tendency was missing. In the same line, knowledge about climate change is limited to the changes between seasons or weather conditions (see Section 4.2.1.4). This situation reveals that information about these topics is needed in order to increase awareness, adaptive capacity, and should be part of a vulnerability assessment in order to reduce vulnerability.

Although local knowledge has been useful to have a clearer picture about vulnerability in the area, and to build urban flash floods under climate change conditions vulnerability framework, answers for many question do not represent exactly what the interviewee expressed. In this particular case, this is due to the use of a third person between the researcher and local people. Not to be able to speak the local language constituted a barrier that did not allow the researcher to conduct a better interview by asking extra information when the interviewee mentioned something interesting that could have helped in finding new vulnerability indicators. This does not mean that the use of translators is not recommended; however, some time to train them in understanding each question, how to ask, and how to obtain extra information should be considered.

6.2. Application of framework in Ikitelli Mehmet Akif and Ikitelli Atatürk, Istanbul

The application of the framework in an urban environment such as the one in Ikitelli Mehmet Akif and Ikitelli Atatürk demanded an adaptation in the framework and in the approach in order to assess vulnerability. This adapted vulnerability framework (Figure 6-1) included fewer measures and components due to data collection reasons (see Sections 3.3 and 3.5) than the one proposed and presented in Section 4.3. The overall result in the form of a vulnerability index (Figure 5-2) indicates that the study area *is* highly vulnerable to flash floods. The spatial variation of vulnerability is influenced mainly by exposure, especially by the three measures within the "physical conditions" dimension, and gives very little information about the socio economic panorama. This result, even though is not the exact same study area, coincides with Ozcan and Musaoglu (2010) in which high and medium vulnerable zones were also located in areas closer to Ayamama river with industrial land use.

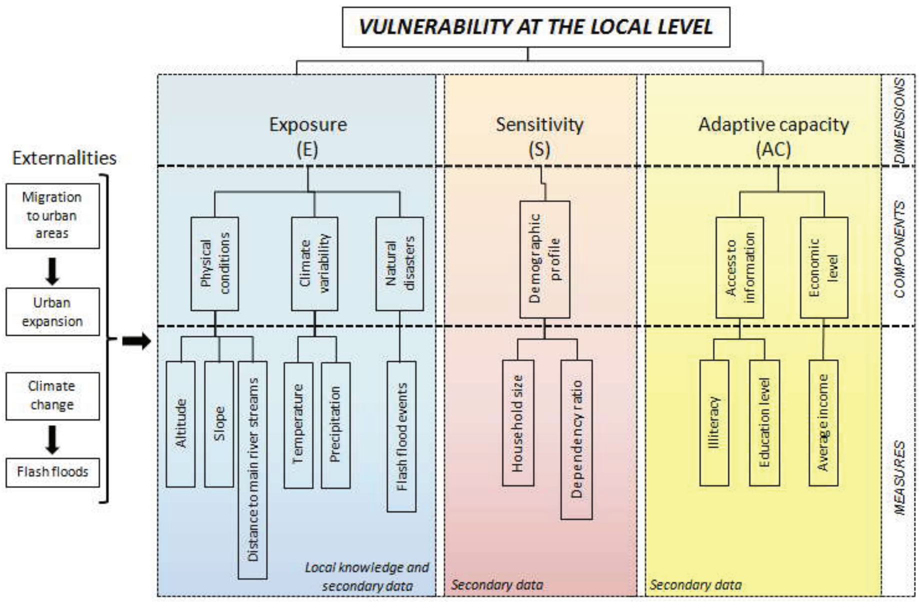

Figure 6-1 Adapted urban flash floods under climate change conditions vulnerability framework

The fact that some measures are missing *does* change the final vulnerability assessment. It has been stated that within a vulnerability to climate change, the adaptive capacity dimension has more importance (see Section 4.3.3), which was translated into a higher weight of this dimension in the SMCE (see Section 5.4).

However, most of the measures missing (knowledge about climate change, participation in disaster preparation campaigns, participation in local organizations, organized preparation campaigns, and workshops) belong to this dimension, resulting in a gap in the assessment.

The results showed that the spatial scale of secondary data regarding sensitivity and adaptive capacity used in the assessment is too large. In the case study area, using data at the neighborhood level does not tell us much since these two neighborhoods are homogeneous. However, this figure would change if: a) all the neighborhoods within the Ayamama river basin were included in the assessment such as in the social vulnerability study in Pendik, Istanbul (Haki et al., 2004), b) if the neighborhood were disaggregated into smaller units such as groups of cadastral blocks or households. Then, for the first case, heterogeneity among neighborhoods from different districts would be visible; for the second case, even though differences within these two neighborhoods are less evident, they would also be represented.

A crucial step in the SMCE process was constituted by the weighting because the final index will vary depending on the weights assigned to each measure, dimension and component. Despite the different available methods to assign weights, they are considered to be a matter of two things: subjectivity and knowledge of people in charge of assigning these values (Eakin and Bojórquez-Tapia, 2008) which is one of the critics to this kind of approach. In this research, weighting has been assigned based on scientific literature that incorporated the same parameters that were used here and personal knowledge about the study area. However, the limited amount and spatial scale of data would not make much difference if a variation in the weight values were applied. This indicates that data from local knowledge and secondary data at a smaller unit such as household is really needed to assess vulnerability at the local level.

Regarding the approach used to downscale the urban flash floods under climate change conditions vulnerability framework, it was not entirely participatory since local people were only involved in answering the survey questionnaire, a kind of participation that Lynam et al. (2007) consider as extractive because the participant was used merely as a source of information. Despite this fact, it has been already shown that local knowledge in Ikitelli Mehmet Akif and Ikitelli Atatürk was useful for understanding and building a vulnerability framework.

6.2.1. Considerations when applying a framework

Applying a framework like this to assess vulnerability in Istanbul has brought up some issues that need to be considered in advance in order to have an appropriate participatory assessment. The way this framework is designed, incorporating in first place local knowledge and also secondary data, requires extensive work during the pre fieldwork phase. First, cooperation between the research team (in charge of the assessment) and local institutions or the local government should exist in theory and in practice. In this way, diffusion campaigns could be organized by the local counterpart in order to inform people about the type of work to be done and all the requirements. Therefore, people would be aware of the ongoing project and this would increase local people's collaboration, which constituted one of the shortcomings for this research.

Second, climate change is a multi-scale problem that involves different actors and time scales (Adger, 2006). Thus, vulnerability assessments to climate change need to consider ways of incorporating different actors' knowledge in the present and perceptions about future situations, a task that has not been done in this research. This requires a previous identification of the actors which could not be done as well as a more appropriate method that allows for this collection of information based on what is already known about the number of actors, and time issues. In Ikitelli Mehmet Akif and Ikitelli Atatürk, survey questionnaires applied through interviews (see Section 3.3) were useful for collecting data from local inhabitants about their perception towards vulnerability to flash floods in the area; however, focus group discussions would have fomented not only more participation but also more consistent answers. Voinov and Bousquet (2010) affirm participatory sessions help standardize information among participants because the different opinions/answers can be cross checked, having more reliable answers.

Third, in areas where cultural codes are strong and part of the inhabitant's daily life such as in the study area, the application of a framework to assess vulnerability and its approach should incorporate this issue. For instance, it should consider the presence of women in the research team in order to assure local women participation and avoid one of the characteristics of the data collection: strong male presence (see Section 3.3). In a Muslim environment, like in the study area, all participatory activities like focus groups or meetings or interviews should be organized according prayer hours to assure the presence of inhabitants. Moreover, the assessment should be able to link these beliefs with vulnerability.

Fourth, vulnerability assessments should incorporate in *a posteriori* phase the presentation and diffusion of the outputs to all the participants. By doing this, the assessment fulfills one of its purposes –to increase awareness (see Section 4.3.3)-, because participants will see how the information they gave has been used to identify vulnerable areas. Fazey et al. (2010) considers this as a positive impact because people will have learnt more about their urban environment, and better adaptation actions can be developed by them.

6.2.2. Applicability of the framework in a developing country

Similar urban contexts like the ones in Ikitelli Mehmet Akif and Ikitelli Atatürk in Istanbul: informal expansion of residential areas –many of them over protected areas or areas exposed to hazards elements such as rivers- due to changes in legislation or amendments in urban plans (ARK TERA, 2009), can be found in many developing countries. The success of the applicability of a framework with these characteristics (see Section 4.3) is context, data and method–dependant. Particular contexts may force a change in ideas and questions to research (Fazey et al., 2010). In this case, part of the framework, the scale of study, and target population were modified because of organization issues, people not willing to collaborate, and cultural barriers.

Data availability also influences in the application of a vulnerability framework and in the results. This research showed that socio economic data per neighborhood is not enough for assessing vulnerability at the local level. For assessing urban vulnerability, data at a smaller scale is necessary to differentiate areas within neighborhoods.

Finally, a framework like this should evaluate carefully the proposed approach based on previous testing and field visits whose purposes is to recognize the study area. This kind of framework to assess urban vulnerability related to flash floods under climate change conditions incorporating local knowledge is applicable in a developing country if there are huge backstage efforts prior to the assessment.

7. Conclusions and recommendations

7.1. Conclusions

Recalling the specific objectives and research questions (see Section 1.3.2), the following conclusions were drawn:
Different approaches varying in their scope and methods employed have been successfully or not used in order to assess vulnerability. Within these, the role of participatory approaches is to focus on stakeholder's experiences in order to build knowledge, obtain data –where it is unavailable- and evaluate alternatives to assess vulnerability.

The urban flash flood under climate change conditions vulnerability framework contributes to the vulnerability assessment issue with a more inclusive approach that uses local knowledge from inhabitants as a source for building proxy indicators. In the area, the following measures that contribute to vulnerability are: distance to river streams, number of damaged houses with the first levels flooded, number of flash floods, knowledge about climate change, number of organized preparation campaigns, number of people participating in preparation campaigns, participation in local organizations. These indicators are later incorporated with other parameteres that come from existing frameworks to assess urban vulnerability at the local level. Moreover, this framework has the particulatiry that it can be updated depending on the context of the area in which it will be applied, and on the knowledge of participants and researchers.

This research has showed that local knowledge plays an important role in vulnerability assessments related to flash floods under climate change conditions. In the study area, people perceive that flash flood events will increase in frequency due to climate change; however, this is not translated into adaptive actions. Not only is local knowledge useful for understanding the specific context regarding vulnerability in the study area, which constitutes a starting point for the assessment, but also a source of information from which context–specific parameters can be developed.

To assess vulnerability related to flash floods in Istanbul demands an adaptation in the framework and in the approach in which local people's participation was only to give information and fewer measures were incorporated in order to calculate the vulnerability index. Despite this, the result showed that the study area is highly vulnerable to flash floods. The spatial variation of vulnerability is influenced mainly by exposure, especially by the three measures within the “physical conditions” dimension, but gives very little information about the socio economic panorama. The major shortcomings when applying this framework in the study area are related to data scarcity, spatial scale of data, and participation from local people.

7.2. Recommendations

To go to the study area prior to the research proposal phase in order to have a clear idea about the extension and other context issues. This would avoid wate of time and resources.

To apply the same framework incorporating other participatory tools besides survey questionnaires in order to collect data for all the measures proposed. In the same sense, to involve different stakeholders in all the steps of the vulnerability assessments, and to apply different weight to each of the parameters involved in the SMCE.

To utilize meteorology data in order to model future precipitation conditions and estimate occurrence of flash flood events in the study area.

To return to study area with the aim of communicating the vulnerability results to local people as well as to all participants so they see the usefulness that the information they provided had. This would in turn increase local knowledge and awareness in the area.

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9. Appendices

9.1. Appendix A. Figures

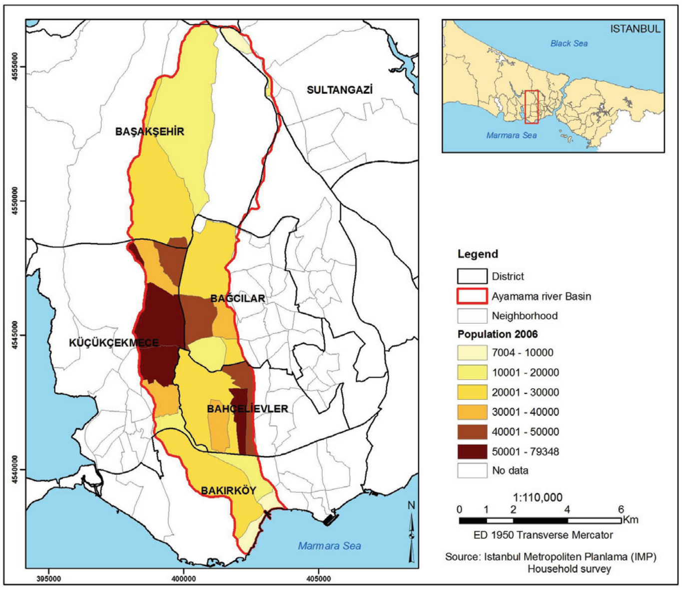

Figure 9-1 Total population in Ayamama river basin, 2006

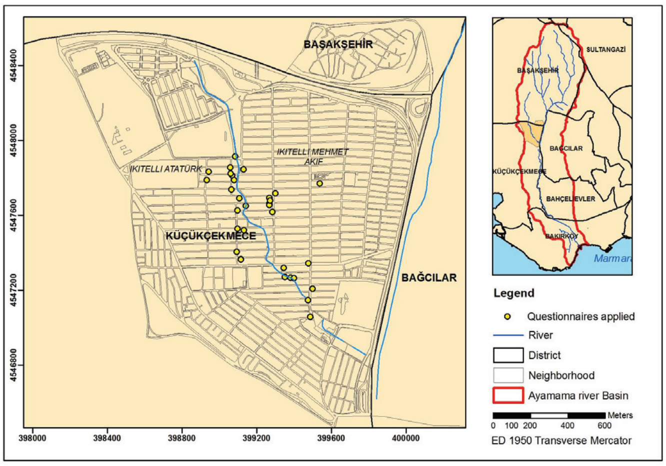

Figure 9-2 Location of questionnaires applied to local people

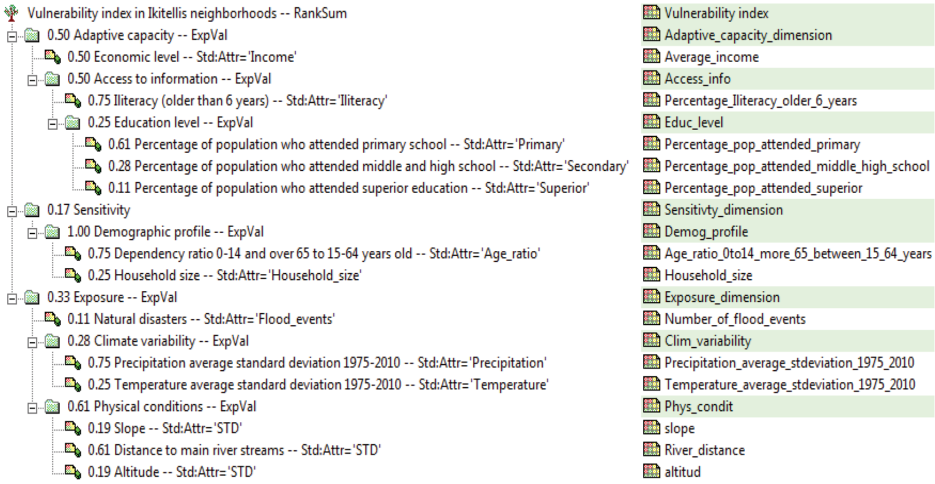

Figure 9-3 Criteria tree in ILWIS

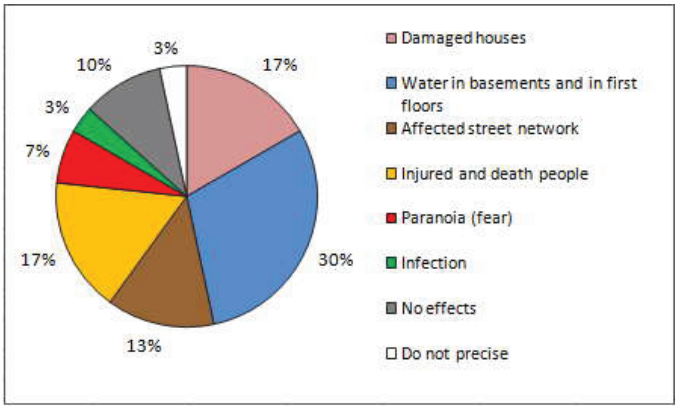

Figure 9-4 Negative consequences during flash floods in 2009

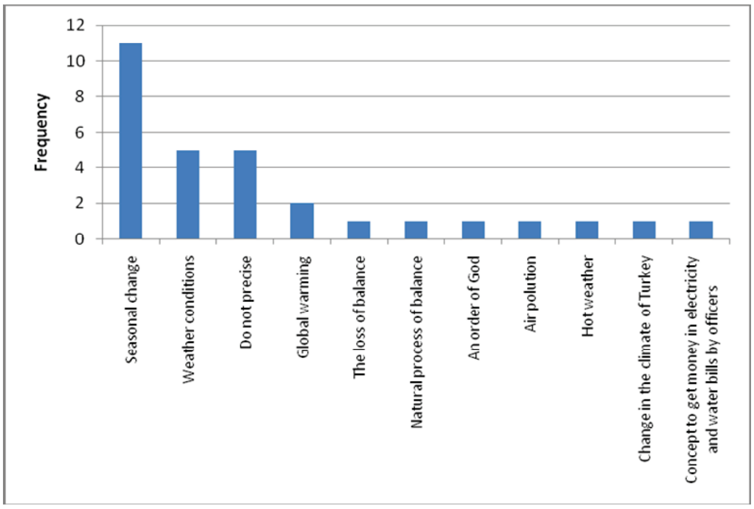

Figure 9-5 Climate change perception in the study area

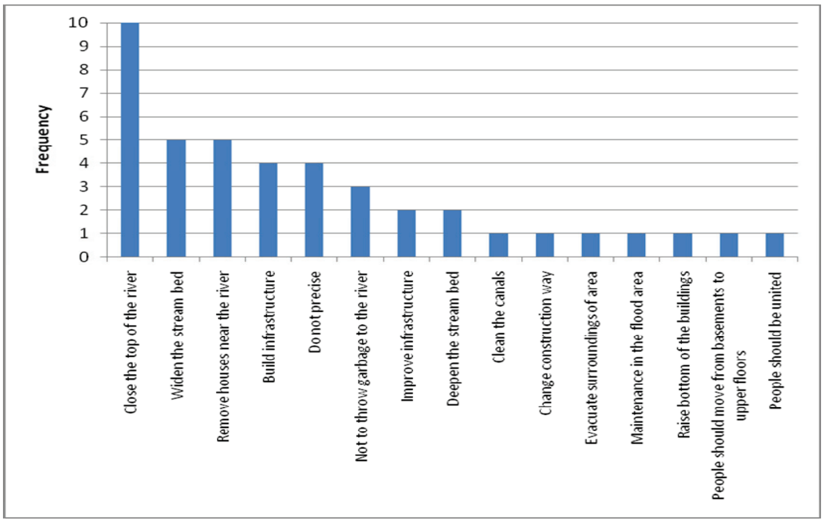

Figure 9-6 Actions to reduce the consequences of floods

9.2. Appendix B. Questionnaire template to local people

Sex: M F

Age: ....

Occupation: ....

1.1 How long have you been working or living in this neighbourhood?
....

1.2 Do you think this neighbourhood is vulnerable to flash floods? Why?
....
....
....

1.3 What were the most negative consequences of the floods last year in the area (neighbourhood)?
....
....
....

1.4 Who do you think was responsible for the consequences of the floods last year?

Weather (rain)	
Government (municipality)	
Other institutions	
Inhabitants	
Closeness to river	
Other (explain)	

1.5 Before the flood of Ayamama river last year:

1.5.1 Was there any flood preparation campaign organized by the Municipality or any official institution?

Yes / No

If YES,
How many and when? ....

1.5.2 Do you think these kinds of preparation campaigns are important? Yes / No
Why?

....
....
....
....

1.6 'What do you understand by "climate change"?

....
....
....
....

1.7 Do you think the occurrence of floods like last year will increase or decrease? Why?

☐ Increase ☐ Decrease

....
....
....
....

1.8 What do you think could be done in order to reduce the consequences of floods?

....
....
....
....

IF NOTHING RELATED TO ORGANIZED INHABITANTS IS MENTIONED IN THE PREVIOUS QUESTION, PLEASE ASK:

1.9 Do you think that it is important to have organized people (in committees, or local organizations) to reduce the consequences of floods? Why?

....
....
....

1.10 How many times has this area been affected by floods in the past 20 years?

....

9.3. Appendix C. Questionnaire template to neighborhood governors: muhtars

1.1 How many times has this area been affected by floods in the past 20 years?
....

1.2 Do you think this neighbourhood is vulnerable to floods? Why?
....
....
....
....

1.3 What were the most negative consequences of the floods last year in the neighbourhood?
....
....
....
....

1.4 Before the flood of Ayamama river last year:

1.4.1 Was there any flood preparation campaign organized by the Municipality or any official institution?

Yes / No

If YES,
How many and when? ....

1.4.2 Do you think these kinds of preparation campaigns are important? Yes / No
Why?
....
....
....

1.5 What do you understand by “climate change”?
....
....
....
....

1.6 Do you think the occurrence of floods like last year will increase or decrease? Why?

☐ Increase ☐ Decrease

....
....
....
....

1.7 What would you recommend to do in order to reduce vulnerability to floods in this area? Explain briefly your suggestions. *IF NOTHING RELATED TO ORGANIZED INHABITANTS IS MENTIONED, PLEASE ASK ABOUT WHETHER THE MUHTAR CONSIDERS IMPORTANT THE FACT THAT ORGANIZED PEOPLE (IN COMITEES, OR LOCAL ORGANIZATIONS) HELP REDUCE VULNERABILITY*

....
....
....
....