Mainstreaming Risk Assessment into Spatial planning for Risk Reduction

Case Study of Urban Flood in Alexandria, Egypt

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July 2020

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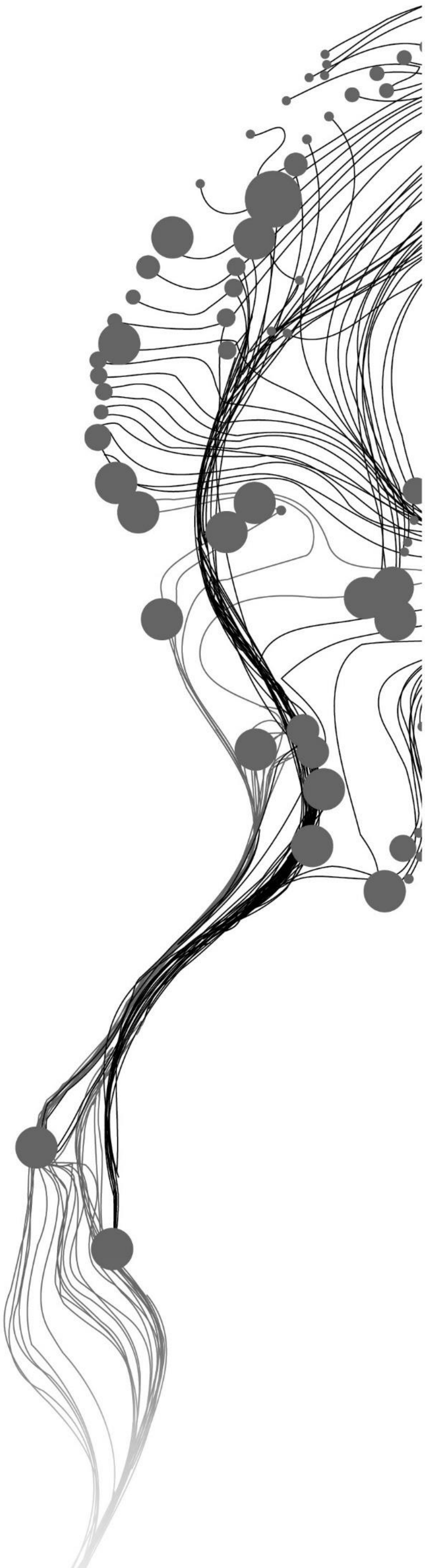

Mainstreaming Risk Assessment into Spatial planning for Risk Reduction

Case Study of Urban Flood in Alexandria, Egypt

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ABSTRACT

The global urbanization trends go hand in hand with the escalating risk from natural hazards owing to climate change. Spatial planning has great potentials in reducing the risk of natural hazards by disentangling the conflict between where people live and where natural hazards hit. Though the globally ascending recognition of the spatial planning role in this endeavor, the followed planning practices in the developing countries rarely contribute to risk reduction. This was owed to deficiencies in these practices as they lack the proper methods for analyzing and understanding risk. On the other hand, risk assessment excels in providing the risk management process with the required analysis to comprehend the natural hazard risk and act accordingly. Thus, the inclusion of risk assessment in the spatial planning process will increase its capacity to comprehend risk and produce proper plans.

The conducted spatial plans in Egypt have minimal influence on risk reduction. Thus, the main aim of this research is to demonstrate how risk assessment can be mainstreamed in the mechanism of the spatial planning framework in Egypt to improve risk reduction. Alexandria city was taken as a case study for this demonstration as the city possesses economic and historical importance, as well as its high exposure to urban flood owing to extreme rainfall events.

A questionnaire was directed to the spatial planning experts in Egypt to draw a holistic description of the current relations between spatial planning, risk reduction, and the extent of utilizing the risk assessment as a planning tool. Urban flood simulation was provided for analyzing the extreme event of rainfalls in Alexandria on the 4th of November 2015. Additionally, the Principal Component Analysis (PCA) was used to conduct a multidimensional vulnerability assessment for the physical, social, and economic dimensions. Thus, the available institutional databases in Egypt, such as census and city's physical geodatabase, were used on the level of the smallest administrative units named Shyakha. Risk is an outcome of combing the maximum flood depth in each Shyakha and its aggregated vulnerability score from the three vulnerability dimensions. Respectively, risk mapping and statistical analysis were used to demonstrate the variations in risk between Shyakha units.

The questionnaire's participants perceive risk reduction as one of the planning goals. However, it was confirmed that risk assessment is not used as a planning tool. The provided hazard information for planning purposes was found to be scarce, while the available institutional databases are sufficient to obtain the hazard information. The experts highlighted the obstacles as well as possible improvements of risk assessment integration into spatial planning. These obstacles and improvements were grouped into aspects that relate to 1) methods, 2) data, 3) communication, 4) institutional integration, 5) funds, 6) expertise and knowledge, and 7) laws and regulation. PCA utilized 38 indicators distributed on three vulnerability dimensions, while the process eliminated 20 indicators. El-Gomrok neighborhood (the oldest in Alexandria city), contains the units with the highest vulnerability. The hazard and the vulnerability combination revealed that the highest risk in the city was a combination of middle values of hazard and vulnerability, which are located in the units of El-Montazah neighborhood.

Several mainstreaming strategies were followed worldwide to adopt new goals within a functioning organization, and these strategies need to be adopted in Egypt to address the 7 aspects of obstacles and improvements and to consider the implementation of objective methods to increase transparency and clarity of the assessment's results and the decisions that follow them.

Keywords: spatial planning, natural hazards, vulnerability, risk assessment, mainstreaming, PCA.

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LIST OF ABBREVIATIONS AND GLOSSARY

Abbreviations

Abbreviation	Details
AAT	Ambulance Arriving Time
AHP	Analytical Hierarchy Process
ASR	Ambulance Services Ratio
CAPMAS	the Central Agency for Public Mobilization and Statistics
DEM	Digital Elevation Model
DPRI	Disaster Prevention Research Institute
EEAA	Egyptian Environmental Affairs Agency
EMA	Egyptian Meteorological Authority
GOPP	General Organization of Physical Planning
GSA	General Sectorial Analysis
KMO	The Kaiser-Meyer-Olkin
NARSS	National Authority for Remote Sensing and Space
NCCDMRR	The National Committee for Crisis/ Disaster Management and Risk Reduction
NUCA	New Urban Communities Authority
OSM	Open Street Maps
PCA	Principal Components Analysis
PERSIANN-CCS	PERSIANN-Cloud Classification System
RAT	Rescue Arriving Time
RCI	The Response Capacity Index
RRI	Rainfall-Runoff-Inundation Model
RSR	Rescue Service Ratio
S.W.O.T	Strengths, Weaknesses, Opportunities, and Threats
SDI	Spatial Data Infrastructure
TORs	Terms of References
WDPM	Water Run-off Model

Glossary

Terminology	Definition	Source
Disaster risk	The potential disaster losses, in lives, health status, livelihoods, assets and services, which 10 could occur to a particular community or a society over some specified future time period.	(UNISDR, 2009)
Exposure	People, property, systems, or other elements present in hazard zones that are thereby subject to potential losses.	
Vulnerability	The characteristics and circumstances of a community, system or asset that make it susceptible to the damaging effects of a hazard.	
Strategic Spatial Plan	It is the plan that determines the future vision of socio-economic and urban development by using participatory approaches. It could be implemented on the national, regional, governorate, Markaz, city, or village levels. It also depicts the goals, policies and plans for social, economic, physical, and environmental development necessary to achieve sustainability. Moreover, it identifies future needs for urban expansion, development projects, various land uses, programs, priorities, implementation mechanisms, and funding sources.	(GOPP, 2015a)

1. INTRODUCTION

1.1. Background and justification

Natural hazards are continuously testing the safety of our communities and position them to the risk of disaster occurrences. However, risk cannot exist without spatial or temporal exposure of the communities to natural hazards. Accordingly, exposure is a primary condition for risk existence and it also contributes to determine the degree of risk (IPCC, 2012). In addition to exposure, communities' vulnerability and hazard features (e.g. intensities and frequencies) are significant contributors to the risk degree. Communities' vulnerability determines their capacity to withstand the effects of the hazards, whereas hazards' intensities and frequencies determine the momentum of the hazardous events (IPCC, 2012). Nevertheless, the conflict between natural hazards and communities are subject to constant changes. The global trends of urbanization increase both the exposure and the vulnerability of our communities, especially in developing countries (Fiala, 2017; UN, 2014, 2017). On the other hand, the momentum and the frequency of the hazardous events are increasing owing to climate change (IPCC, 2018).

Risk management is the process of assessing, intervening, and monitoring risk in order to reduce the risk of disaster occurrences or the consequences that follow hazardous events (Fleischhauer, 2008; Greiving & Fleischhauer, 2006; Wamsler, 2014). Risk assessment is the initial phase in this process, and it is concerned with analyzing risk and supporting the decision-making process (Greiving & Fleischhauer, 2006). Risk management follows the so-called risk cycle that consists of four phases 1) mitigation/prevention, 2) preparedness, 3) response and 4) recovery; phases 1 and 2 are associated with pre-disaster measures, while 3 and 4 are related to during and post-disaster measures; risk assessment supports the decision-making throughout theses phases (Fleischhauer, 2008; Wamsler, 2014).

Best practice in risk management is based on applying integrative structural and non-structural measures while considering the impacts of these measures on the physical, socio-economic, and ecological dimensions (Greiving & Fleischhauer, 2006). The integration of measures should consider the plans of the sectorial risk management authorities on different spatial levels. Risk management is part of a methodological process that can be optimized for different spatial contexts and scales. (Greiving & Fleischhauer, 2006; Wamsler, 2014).

Spatial planning is mainly striving to eliminate the spatial link between hazards and the exposed assets; by reducing the intensities of the hazards or reducing communities' vulnerability. Accordingly, spatial planning utilizes different instruments such as land use planning and building regulation to customize suitable structural and non- structural measures for risk reduction (Fleischhauer, 2008; Wamsler, 2014). Since spatial planning is a methodological process, it can be customized to different spatial contexts rather than implementing the same measures for different contexts. Spatial planning nature (as an integrative procedure) can combine the sectorial plans from the relevant institutions, and thus, consider multiple risks for all relevant hazards (Greiving et al., 2006). Spatial planning has the capacity to consider the interrelation between the designed measures and their impacts on the physical, socio-economic, and ecological dimensions (Fleischhauer, 2008; Greiving & Fleischhauer, 2006; Wamsler, 2014).

It is indispensable to integrate risk assessment with spatial planning (Greiving & Fleischhauer, 2006; ISDR, 2005; Wamsler, 2014). Accordingly, risk assessment could improve spatial planning understanding to risk, and respectively, improving the relevant decision making for measures (Greiving & Fleischhauer, 2006; Wamsler, 2006, 2014). Since the vulnerability information is well provided for spatial planning usage, an improvement in the vulnerability assessment is foreseeable to consider multidimensional aspects (e.g.

physical, social, economic, etc.). Nevertheless, the hazard information is usually scarce to planning, thus, there is a need to provide or collect them from the responsible sectorial authorities (Greiving & Fleischhauer, 2006; Wamsler, 2014).

There is a lack of cooperation between experts in risk management and spatial planning (Wamsler, 2004, 2006, 2014). Spatial planners might not perceive risk reduction as a spatial planning goal while it is the main goal for risk management experts. Furthermore, communicating information between both fields' experts is hindered by the differences in the educational and professional backgrounds (Wamsler, 2006, 2014). Additionally, each field operates under separate institutional framework with different operational methods, and their allocated funds are for separate purposes (Greiving & Fleischhauer, 2006; Wamsler, 2006, 2014). Therefore, general consideration of risk reduction into spatial planning is questionable, especially in developing countries, even though they are the most exposed to natural hazards, and have the highest vulnerability (Fiala, 2017; UN-Habitat, 2017; UN, 2015). Recently, progress has occurred in several countries in integrating risk management with spatial planning fields and several organizations are consistently emphasizing this integration, especially in developing countries (ISDR, 2005; UN-Habitat, 2017; UN, 2015)

1.2. Study scope and area

Egypt as a developing country encounters several challenges related to risk reduction. Spatial planning and risk management are mostly being conducted in isolation from each other (IDSC, 2008, 2010; World Bank, 2014). Risk management in Egypt is mainly the responsibility of sectorial authorities such as civil defense, health, social affairs, governorates, water resources, and environment agencies (IDSC, 2008, 2010). Spatial planning's laws, regulations, guidelines, and Terms of References (TORs) do not require risk reduction as a planning goal, and thus, risk reduction is not reflected in the produced plans. Furthermore, the followed spatial planning process lacks the tools for risk analysis and assessment, which impede the rational decisions for risk reduction (Greiving & Fleischhauer, 2006; IDSC, 2008, 2010; World Bank, 2014).

Risk assessment studies in Egypt are not common practice and encounter several obstacles. First, the hazard assessment is not a standardized process as hazard information is being produced by separate authorities such as "the Egyptian Environmental Affairs Agency (EEAA)" and "National Authority for Remote Sensing and Space (NARSS)". Thus, the process of producing hazard maps is not consistent. Furthermore, the weak communication between these authorities and the spatial planning authority restrains hazard information exchange (Greiving & Fleischhauer, 2006; IDSC, 2008, 2010). Second, vulnerability assessments either focus on one dimension of vulnerability (mostly the physical) or they subjectively utilize a small set of variables for the social and economic dimensions. These studies do not provide a clear rationalization for the selection of indicators or the application of weights (Eckert et al., 2012; El-Barmelgy, 2014; El-Boshy et al., 2019; El-Hattab et al., 2018b; Mohammed & Raey, 2019; World Bank, 2011a). These deficiencies are owing to the lack of vulnerability data for the sectoral authorities and risk assessment experts, which results in insufficient inputs to the vulnerability assessment. On the other hand, vulnerability data is well provided for the spatial planning process by several institutional databases (e.g. census data and physical geodatabases, etc.) (Greiving & Fleischhauer, 2006; IDSC, 2008, 2010).

Alexandria is a major coastal city in Egypt, and it is the second metropolitan city after Cairo. The city possesses significant attention from decision-makers and worldwide investors owing to its historical importance and economic potentials (GOPP, 2008; World Bank, 2011b). Alexandria is encountering several challenges related to natural hazard risk as it is highly exposed to several hazards owing to its location by the Mediterranean coast and its topographic features. Furthermore, the city's vulnerability is increasing owing to its rapid growth, of which it is mostly unregulated (World Bank, 2011b, 2011a, 2014). Extreme rainfall events are becoming more frequent owing to climate change, which increase the city's exposure to the risk of urban flooding. Alexandria has observed its worst urban flood event on the 4th of November

2015, which caused severe damages in both lives and assets (El-Boshy et al., 2019; World Bank, 2011b; Zevenbergen et al., 2017). Therefore, urban flood risk in Alexandria will be taken as a good example to demonstrate an objective approach for conducting risk assessment to support spatial planning.

The ex-ante arguments reveal a gap in utilizing spatial planning in risk reduction for several reasons including: the weak integration between the relevant authorities; the current spatial planning practices are missing risk analysis tools; the current risk assessment practices do not serve the spatial planning needs; hazard information is mostly hard to acquire, as well as vulnerability assessment is mostly insufficient and subjective. Accordingly, further understanding is needed for the current relations between risk assessment and spatial planning practices in Egypt, as well as investigating the latent reasons that could hinder their integration to achieve risk reduction. Moreover, it is important to identify the potential needed improvements from the planner’s point of view to achieve this integration. Consequently, improving the integration between risk assessment and spatial planning will enable the latter to contribute effectively in risk reduction.

1.3. Research problem

The current spatial planning practices in Egypt do not contribute to risk reduction despite the ascending global recognition of spatial planning's role in this endeavor (Greiving & Fleischhauer, 2006; IDSC, 2008, 2010; Wamsler, 2014). The spatial planning practices in Egypt do not provide planners with the needed risk analysis for decision making. This deficiency is the result of the absence of mainstreaming risk assessment into the spatial planning practices in Egypt (IDSC, 2008, 2010; World Bank, 2014). As a result, the measures of urban flood risk reduction in a coastal city such as Alexandria lack the significant contributions from spatial planners, though the city is highly exposed to flood risks owing to its rapid growth and the impacts of climate change (World Bank, 2011a, 2011b, 2014).

The weak linkage between risk assessment and spatial planning in Egypt is owed to deficiencies in the two main components of risk assessment: hazard and vulnerability assessments. Firstly, hazard information is mainly the responsibility of sectorial authorities, of which communications with the spatial planning authority are missed. Thus, hazard assessment is usually disregarded from spatial planning usage (Greiving & Fleischhauer, 2006; IDSC, 2008). Secondly, though the vulnerability information is well provided for spatial planning, vulnerability assessment disregards a multidimensional assessment, as well as lacking objectivity in indicators selection and weighting (Greiving & Fleischhauer, 2006; IDSC, 2008, 2010; Reckien, 2018; Yoon, 2012).

Accordingly, risk assessment needs to be systematically mainstreamed in the mechanism of the spatial planning framework in Egypt. This will enable it to become an instrument of risk analysis while taking into consideration the effective and informative communication of risk to spatial planners. Eventually, mainstreaming risk assessment into the spatial planning process will enable planners to identify intervention priorities and suitable measures. Respectively, planners will utilize the spatial planning tools - land-use zonation, building regulations, etc.- in developing suitable scenarios that limit/reduce risk.

1.4. Research objectives

1.4.1. Main objective

The main aim of this research is to demonstrate how risk assessment can be mainstreamed in the mechanism of the spatial planning framework in Egypt to improve risk reduction.

1.4.2. Sub-objectives and research questions

Objective 1: To describe the current relations between natural hazards' risk assessment and spatial planning practices in Egypt.

Q1: What are the contributions of risk assessments in the current spatial planning practices in Egypt?

Q2: What are the obstacles of mainstreaming risk assessment into spatial planning and possible improvements?

Objective 2: To analyse the worst observed urban flood event in Alexandria, the storm of the 4th of November 2015.

Q3: How can urban flood hazard information be analyzed for this event?

Objective 3: To objectively assess the vulnerability of Alexandria city to urban flood hazard.

Q4: What are the suitable indicators for assessing the multidimensional (social, economic, physical) aspects of vulnerability in the context of urban flood in Alexandria?

Q5: How can institutional databases (e.g. census data and physical geodatabases, etc.) be utilized to assess the different dimensions of the vulnerability by Principal Components Analysis PCA?

Objective 4: To provide an informative risk assessment for spatial planning in Egypt.

Q6: How can risk information be analysed for the use of spatial planning?

1.5. Research methods in design

The previously mentioned research questions will be answered throughout four main phases. The first phase will utilize an online questionnaire for the planning experts in Egypt to understand the current relations between risk assessment and spatial planning from the planners' point of view. Respectively, a description will be provided for the planners' perception of the risk concepts and their role in risk reduction. Additionally, the obstacles that hinder the integration between risk assessment and spatial planning will be identified, as well as the possible improvement from the planners' perspective. The second phase will result in mapping and analyzing the worst observed urban flood event in Alexandria on the 4th of November 2015. Accordingly, the urban flood inundation depth and spatial extent will be produced by Rainfall-Runoff-Inundation (RRI) (Bhattacharya et al., 2018; El-Boshy et al., 2019; Saber et al., 2020). The third phase will utilize the (PCA) to conduct a multidimensional vulnerability assessment. PCA has shown promise in objectively dealing with numerous variables, which usually result from census information and physical geodatabases. It reduces a large set of variables to a smaller set of uncorrelated factors that explain the overall variance in variables (Cutter et al., 2003; Reckien, 2018; Yoon, 2012). Moreover, it provides an objective approach for testing the relevance of the used variables, as well as weighing the resulted factors (Reckien, 2018; Török, 2018; Yoon, 2012). Finally, the risk assessment will be conducted for the urban flood context in the city of Alexandria by combining the hazard with the vulnerability information, and respectively, the exposed assets will be quantified for the different risk degrees (CENN & ITC, 2012; El-Barmelgy, 2014; El-Barmelgy & Sebaway, 2017).

2. LITERATURE REVIEW

This chapter will be mainly concerned with demonstrating the relevant literature to the risk assessment and spatial planning. Floods will be used in this chapter as the selected hazard to be further investigated as it is considered the most prominent hazard globally. Moreover, the chapter will further present the effects and impacts of floods hazard on Egypt. Subsequently, the commonly used approaches for conducting vulnerability assessment will be introduced, in addition to the commonly used indicators for assessing vulnerability to flood on both global and local (Egypt) levels. Respectively, risk assessment approaches will be presented, followed by a brief elaboration of the possible contribution of spatial planning in risk reduction and the reasons that hinder planning form contributing to this endeavor. Furthermore, possible strategies for mainstreaming risk reduction practices will be introduced along with their associated activities. Finally, a conceptual framework will be illustrated to demonstrate the missing links between risk assessment and spatial planning.

2.1. Natural hazards

2.1.1. Flood Hazard

Floods are the most frequent hazard worldwide and they cause considerable losses every year, that include loss of lives and properties, developing countries in particular are considerably effected by it (El-Boshy et al., 2019; Fiala, 2017). Flood can be described as a temporary and an undesirable increase in the amount of water outside its natural or manmade streams or locations which leads to negative consequences. Therefore, floods occur when the amount of water exceeds the ability of natural processes -evaporation, infiltration, discharge- to dispose of it or urban drainage networks to absorb it. The existence of water source such as rainfall or snowmelt that interacts with other natural processes such as Ice jam, ground failure or rockfall can lead to extreme flooding events. Moreover, flood can happen due to failure in artificial flood control structures (EXCIMAP, 2007; Wright, 2007a; Zevenbergen et al., 2010).

The flood causes are a combination of three major aspects 1) water source 2) Process intensity in time 3) location characteristics. Table 2-1 illustrates the aspects that cause flooding. Consequently, the commonly used terms to describe floods' types are a manifest of the interrelation between these aspects. These terms aim at expressing a description and explanation of the variability in these three aspects, which contribute to the occurrence of a specific type of flooding event. Most likely, different locations could experience exposure to different flood hazard types. Thus, it is crucial to identify these types on local bases and their drivers for efficient risk management (Kundzewicz et al., 2014; Turkington et al., 2016; Wright, 2007b).

2.1.1.1. **Flood types and causes**

Flood events from different types could happen individually, simultaneously or consecutively (Kappes et al., 2010; Leonard et al., 2014; Zevenbergen et al., 2010). The most common types are: river flood, flash flood, coastal flood, and urban flood (IPCC, 2012; UN-Habitat, 2010; Wright, 2007b).These types are described as follows:

River flood (Alluvial flood): it is an abnormal increase in the height and flow speed of a river owing to intense rainfall, dam failure or ice jam (Wright, 2007b).

Flash flood: it is an abnormal and rapid increase in height and flow speed of a water stream (natural or artificial) owing to intense rainfall, dam failure or ice jam, thus it is considered as a subtype of river flood; usually, it carries a considerable amount of debris (Wright, 2007b).

Coastal flood: It is associated with an increase in the elevation of coastal water from seas or oceans owing to tropical storms, cyclones, tsunami, tidal waves and sea level rise (UN-Habitat, 2010; Wright, 2007b).

Urban flood (pluvial flood): It occurs owing to lack of soil infiltration or inadequate infrastructure, which prevent the water on the ground's surface to be absorbed or disposed of. In urban areas particularly urban flood happens because of poor urban drainage network and low surfaces permeability. Usually, developing countries are highly exposed to this type of flooding (El-Boshy et al., 2019; Wright, 2007b).

Table 2-1: The aspects that cause flooding

1) water source	2) Process intensity in time	location features
Rainfall Snowmelt Sea storm surge Groundwater	Low intensity – Short time Low intensity – Long Time High Intensity – Short time High Intensity – Long Time	Climate Topography (Elevation-Slope) Landcover Soil Water bodies

2.1.2. The significance of flood hazard in Egypt

Flood is the most prominent hazard in Egypt, flood intensity and frequency have recently increased and continue to increase. This increase is owing to climate change, which caused more frequent and intense rainfall events; thus, rainfall is considered to be the main triggering factor for flood hazard in Egypt. Moreover, flood impacts are continuously aggravating due to unplanned urban growth, as well as the densification of population and activities; this is accompanied with insufficient and unprepared infrastructure, which cannot cope with the increasing trend of rain events (El-Boshy et al., 2019; Saber et al., 2020; World Bank, 2014). Therefore, there are two frequent types of floods in Egypt, 1) flash flood and 2) urban pluvial flood (Saber et al., 2020; World Bank, 2014). There is no sufficient distinction between these two types of floods in Egypt, thus, flash flood is extensively covered by literature (Abdel-Fattah et al., 2015; Cools et al., 2012; El-Magd et al., 2010; Eliwa et al., 2015; Moawad et al., 2016; Ogiso et al., 2017; Saber et al., 2020). On the other hand, urban pluvial flood is rarely investigated (El-Boshy et al., 2019).

Technically, there are intrinsic differences between these two types. Flash flood usually occurs near mountainous and hilly areas where there are variations in elevation and slope (Eliwa et al., 2015). Accordingly, flash floods are witnessed in Egypt in several regions where these features are available; for instance: Sinai Peninsula and Eastern Desert; Red Sea wadis such as Safaga, Ambagi, Ras Gharib and El-Baroud; and Upper Egypt locations such as Assiut, Sohag, Qena and Aswan (Saber et al., 2020). Whereas urban flood happens owing to poor infrastructure and impermeable surfaces in urban areas (Wright, 2007b). Thus, it has been witnessed frequently in metropolitan cities such as Cairo and Alexandria (El-Boshy et al., 2019; Saber et al., 2020). However, the eastern expansions of Cairo is frequently exposed to flash flood, owing to its hilly terrains (Saber et al., 2020).

2.2. Vulnerability assessment

Vulnerability is a main component of risk analysis; vulnerability assessment is usually conducted using several approaches as part of a comprehensive risk assessment study. (Papathoma-Köhle et al., 2017). Three major approaches are identified by Papathoma-Köhle et al. (2017), these approaches includes: 1) vulnerability curves, 2) vulnerability matrices, and 3)Vulnerability indicators. The selection from these approaches determines the followed risk assessment approach, as will be illustrated in the subsequent section 2.3.1 (Papathoma-Köhle, 2016; van Westen & Greiving, 2017).

The following will be briefly presenting these three approaches with emphasis on the Indicator-Based Approach (IBA) owing to it is potential in including multiple vulnerability aspects. Unlike the other approaches, IBM doesn't only consider physical vulnerability, but it can be used to assess social and economic vulnerability aspects as well (Papathoma-Köhle, 2016; van Westen & Greiving, 2017).

2.2.1. Vulnerability curves (quantitative approach)

Vulnerability curves are defined by recorded observations of the occurred damages and losses in assets when they are hit by hazards. Respectively, the recorded degrees of losses are being associated with assets' physical characteristics as well as hazards' type and intensity to which the assets are exposed to (Papathoma-Köhle, 2016; Papathoma-Köhle et al., 2017; van Westen & Greiving, 2017). Accordingly, a function is defined as a continuous curve that represents the loss degrees, which correspond to the assets' physical characteristics and hazard intensities. This curve can be used to estimate and predict the losses in assets for different hazard scenarios, and since losses can be expressed in monetary value, the cost-benefit analysis can be conducted to evaluate protection measures (Papathoma-Köhle, 2016; Papathoma-Köhle et al., 2017; van Westen & Greiving, 2017).

This approach utilizes a significant amount of empirical data samples that require considerable effort, time, and money to be collected. However, the required level of details in the data is relatively low (Papathoma-Köhle, 2016; Papathoma-Köhle et al., 2017; van Westen & Greiving, 2017). This method has gained popularity by risk assessment experts as it provides a quantitative approach for assessing physical vulnerability. Nevertheless, it disregards other aspects of vulnerability (Papathoma-Köhle, 2016; Papathoma-Köhle et al., 2017; van Westen & Greiving, 2017).

2.2.2. Vulnerability matrices (qualitative approach)

This approach follows subjective judgment on the interaction between hazardous events and assets. Accordingly, the relation between hazard intensity and the consequences is described as risk classes (Papathoma-Köhle et al., 2017; van Westen & Greiving, 2017). This approach is based on experts' knowledge and opinions under limited availability of quantitative data, which might differ from one expert to another. It is usually associated with real events to limit the needed information to conduct the assessment (Papathoma-Köhle et al., 2017; van Westen & Greiving, 2017). Though it is highly subjective and it is easy to be communicated to non-experts (Papathoma-Köhle et al., 2017).

2.2.3. Vulnerability indicators- Indicator based approach (IBA)

Deductive and inductive methods are widely used for conducting indicator-based vulnerability assessments (Reckien, 2018). Comparisons have been made between both methods by investigating their implementation requirements and options in terms of indictors' selection, metrics, transformation, weighting, and the difference between their results (Reckien, 2018; Yoon, 2012). The deductive method utilizes a limited number of indicators based on expert knowledge with related theories, literature and local context (Yoon, 2012). On the other hand, the inductive method uses a broader range of indicators, which are reduced to smaller numbers of variables (components) by merging the highly correlated indicators in one component. Thus, PCA is usually used as a reductionist method (Cutter et al., 2003; Reckien, 2018; Yoon, 2012). Though these indicators are drawn from literature, the assessment includes all indicators that concluded to be relevant (Yoon, 2012). This approach is suitable in utilizing a rich source of data such as census (Cutter et al., 2003; Reckien, 2018).

2.2.3.1. Data metrics, normalization, and weighting methods

Data metrics have a profound effect on the vulnerability result. Thus, Reckien (2018) investigated the differences between using indicators in the forms of person per km2 (area-based data) and as a percentage of total residents per tract (population-based data). Reckien argues that using area-based data is preferable as it results in better representation for the spatial variances and it lowers the differences in the results of vulnerability assessment methods. Additionally, it aligns with the policy and planning literature. Nevertheless, the inductive approach provides the advantage of utilizing more indicators in the assessment and reducing the differences in results that might occur because of using different metrics (Reckien, 2018).

Different normalization techniques are presented by Yoon (2012) such as z-score, maximum value (ratio of value), and min-max rescaling transformations. However, based on the sensitivity analysis conducted by Tate (2012) that evaluates the effect of applying different techniques for each step of the vulnerability assessment, the author concluded that these techniques hold a negligible effect on the outcome. Moreover, the use of different normalization methods does not result in significant variance (Yoon, 2012).

Weighing indicators hold a noticeable degree of subjectivity, and it is considered to be problematic (Reckien, 2018; Yoon, 2012). Following the deductive method incorporates weighting schemes either subjectively based on the experts' knowledge by applying the Analytical Hierarchy Process (AHP) or based on literature' frequently mentioned parameters (Reckien, 2018; Tate, 2012). Whereas following the inductive approach is rarely implementing weightings, weights can be applied by multiplying components by the variance they explain (de Sherbinin & Bardy, 2015; Török, 2018), and not necessarily regardless of their contribution to social vulnerability (Cutter et al., 2003; Reckien, 2018; Yoon, 2012).

2.2.3.2. **The pros and cons of the two methods**

The deductive method is usually preferred when the drivers of the vulnerability are clear. In this case, the assessment can utilize a small number of indicators and incorporate the relative importance of each indicator by using weights. However, scholars attempt to avoid the need for using weights as there is a lack of an appropriate method of determining them. Moreover, the influence of the indicators is hidden owing to the summative vulnerability as a final index, which can be solved by mapping individual indicators (Reckien, 2018). Furthermore, this approach is attributed to high applicability because of its clarity to be communicated to stakeholders (Reckien, 2018; Yoon, 2012).

On the other hand, the inductive approach is described as a complex practice that lacks the easiness to be communicated effectively to stakeholders, even though it is the most commonly used approach owing to its relative simplicity in considering all the possible indicators (Reckien, 2018; Yoon, 2012). Nevertheless, Abson et al. (2012) argue that PCA holds an advantage of information richness that enables the understanding of the multi-variance drivers of vulnerability, which can be further improved by mapping each component individually (Reckien, 2018; Yoon, 2012).

Additionally, in order to validate the results of the vulnerability assessment, a comparison should be made with real-world observed impacts and accompanied with statistical analysis, which will highlight the most relevant factors to vulnerability (Reckien, 2018; Yoon, 2012). Decision-makers should be provided with vulnerability assessments using different approaches so that they come to a decision about an approach of their preference (Yoon, 2012). Attention should be given to the effect of the scale in terms of data collection and followed analysis (Tate, 2012; Yoon, 2012).

2.2.3.3. **Vulnerability indicators associated with flood hazard**

Both of the presented indicator-based methods are highly influenced by the selected indicators. Thus, attention should be paid for the nexus between indicators and the different vulnerability dimensions (Tate, 2012). Literature provides the base for the process of indicators' selection (Yoon, 2012). Additionally, the process of identifying essential indicators could be complemented with the knowledge of stakeholders, experts, and local people; however, this process is always limited by the availability of data. Therefore, an emphasis on the potentials of using rich sources of information such as censuses was illustrated by Cutter et al. (2003). Accordingly, Table 2-2 illustrates the commonly used indicators in the flood vulnerability assessment studies in Egypt (coloured cells) and for other relevant studies worldwide.

Vulnerability assessment practices in Egypt

Vulnerability assessment practices in Egypt mainly follow an indicator-based approach, and they are usually conducted as part of comprehensive risk assessment studies or researches. A review of the common practices of vulnerability assessment within the Egyptian landscape is introduced in subsection 2.3.2 "Risk assessment practices in Egypt". The subsection includes a comprehensive description of the development of vulnerability and risk assessment research in Egypt. The conducted assessments focus on the context of Alexandria in relation to hazards such as Tsunami, sea-level rise and urban flood.

Table 2-2:The commonly used indicators for conducting flood vulnerability assessment, coloured cells represent the indicators, which are commonly used in the Egyptian context.

	Indicator	Sub indicator	Relation	Description	Source
Physical Dimension	Urban context	Informal settlements area Slums area Rural lands area	+	Informal areas are attributed with poor physical conditions such as poor infrastructure, poor buildings' structure and high population density, as well as lack of services. Also, rural areas are not sufficiently adjacent to services, low income and highly dependent on local resources.	(Cutter et al., 2003; El-Boshy et al., 2019; Rufat et al., 2015; Yoon, 2012)
	Building construction material	Number of masonry buildings per administrative unit Number of other construction materials buildings per administrative unit	+	Poor building materials increase the fragility of buildings towards floods, some materials keep humidity, thus; it could cause health problems.	(Eckert et al., 2012; El-Barmelgy, 2014; El-Boshy et al., 2019; El-Hattab et al., 2018b; Rufat et al., 2015)
	Building Structure	Number of bearing walls structure buildings per administrative unit Number of other structure buildings per administrative unit	+	Different building structures have different endurance to flooding hazards.	(Eckert et al., 2012; El-Barmelgy, 2014; El-Boshy et al., 2019; El-Hattab et al., 2018b; Rufat et al., 2015)
	Building condition	Number of medium quality buildings Number of low-quality building	+	Poor building conditions increase the fragility of buildings towards floods and increase their susceptibility to damage.	(Eckert et al., 2012; El-Barmelgy, 2014; El-Boshy et al., 2019; Rufat et al., 2015)
	Heath and emergency services availability	Distance form hospitals Number of hospitals	+	Long travel distance to the nearest health facility in case of emergencies increase vulnerability.	(Cutter et al., 2003; El-Boshy et al., 2019; Niyongabire & Rhinane, 2019; Rana & Routray, 2018; Rufat et al., 2015)
	No. of floors/ Building hight	Number of low-rise buildings per square kilometre	+	Low rise buildings and families that lives in houses of two or less floors are more vulnerable to floods.	(Eckert et al., 2012; El-Barmelgy, 2014; El-Hattab et al., 2018b; Rana & Routray, 2018)
	Number of makeshift and mobile houses		+	This type of buildings is of poor quality and can be easily be destroyed by hazards events.	(Cutter et al., 2003; Rufat et al., 2015; Yoon, 2012)
	Infrastructure connectivity	Number of buildings not connected to water Number of buildings not connected to Sewage Number of buildings not Connected to electricity	+	Lack of infrastructure reduces the ability of the community to cope with natural hazards; in case of damages in infrastructure an additional financial burden is placed on the community to compensate these damages.	(Cutter et al., 2003; Rana & Routray, 2018)
	Urban morphology	Density of built Environment	+	High concentration of activities and population increase the exposed assets to hazard	(Cutter et al., 2003; Kablan et al., 2017; Müller et al., 2011)
		Density of open and green spaces	-		

Social Dimension	Population/ Pop density		+	It is used to quantify the exposed population; indicate the level of exposure.	(El-Boshy et al., 2019; El-Hattab et al., 2018b; Rufat et al., 2015)
	Population annual growth		+	Express the changes in population and the corresponding pressure on infrastructure as rapid population growth reduces the capacity of infrastructure to mitigate flooding hazard.	(Cutter et al., 2003; Mohammed, 2017)
	Gender	Number of females	+	Tend to be emotional as they have less physical strength than men, more engaged in the family.	(Cutter et al., 2003; El-Boshy et al., 2019; El-Hattab et al., 2018b; Müller et al., 2011; Rufat et al., 2015)
	Age Extremes	Number of elderlies above 65	+	The elderly population have difficulties in mobility to avoid hazard because of their physical condition.	(Cutter et al., 2003; El-Boshy et al., 2019; El-Hattab et al., 2018b; Kablan et al., 2017; Rufat et al., 2015)
		Number of children under 5	+	Fragile physical condition and dependent on others.	
	Disabilities	Number of disabled population	+	Disabled population encounter difficulties in mobility to void hazard.	(El-Boshy et al., 2019; Rana & Routray, 2018; Rufat et al., 2015)
	Education level and status	Education /Literacy rates	-	Education is connected to the social status, and the ability to understand and respond to warnings and applying mitigation measures.	(Cutter et al., 2003; El-Boshy et al., 2019; Kablan et al., 2017; Müller et al., 2011; Rana & Routray, 2018; Rufat et al., 2015)
		Illiteracy rate	+		
		Number of people cross different education levels (no high school diploma)			
	Marital state (Number of female-headed households, no spouse present)	Widowed	+	Loneliness is associated with vulnerability especially for older population; the absence of one of the parents might pose an extra burden on the family.	(Cutter et al., 2003; Daddoust et al., 2018)
		Divorces			
		Never married			
	Number of rural areas population		+	Rural population are not sufficiently adjacent to services, have lower income and highly dependent on local resources.	(Cutter et al., 2003)
	Households status	Average family size	+	Family with large numbers might suffer from the lack of financial resources which are needed to recover of mitigate the hazard.	(Cutter et al., 2003; Rufat et al., 2015)
		Number of households with 2 rooms and less or the average number of rooms			
		Overcrowding rate			
	Type of tenure	Number of households under old rent law (rent control) in Egypt	+	Renters usually lack the financial resource for buying their own home, they have fewer options for alternative shelters, and they are restricted to apply mitigation the conflict with owners. Controlled rent in Egypt force owners to receive rent values much less than the market value and the contract can be ended by the condemnation of the building and the need to demolish it.	(Cutter, 1996; Rufat et al., 2015; Shawkat, 2018)
		Number of households under other types of rent			

	Households connectivity to Infrastructure	Number of households not connected to water public network	+	Lack of infrastructure reduces the ability of the community to cope with natural hazards; in case of damages in infrastructure an additional financial burden is placed on the community to compensate these damages.	(Cutter et al., 2003; Rana & Routray, 2018; Rufat et al., 2015)
		Number of households not connected to Sewage public network			
		Number of households not Connected to electricity public network			
Economic Dimension	Unemployment	Number of populations outside the labor force	+	Unemployed population encounters difficulties in recovering from harm, as well as applying mitigation measures.	(El-Hattab et al., 2018a; Kablan et al., 2017; Müller et al., 2011; Rufat et al., 2015)
		Unemployment rate			
		Dependency ratio			
	Land use/ Building use	The area of residential / number of residential houses in urban areas / number of rural houses	+/-	Determine threatened residential areas, as well as interrupted services and livelihood.	(Cutter et al., 2003; El-Hattab et al., 2018b)
		The area of commercial and industrial development / number of facilities			
		The area of farmlands / number of agriculture activities' facilities			
	Land or property value		+/-	Indicate the social classes and the expected loss value	(Cutter et al., 2003; El-Barmelgy, 2014; Rufat et al., 2015)
	poverty		+	Poor community encounter difficulties in absorbing disasters effects, also, they recover slowly.	(Cutter et al., 2003; Rana & Routray, 2018; Rufat et al., 2015)
	Social dependence (Per capita Social Security recipients)	Number of retired populations	+	Population with limited financial resources find hardness in coping with disastrous events	(Cutter et al., 2003; Rana & Routray, 2018; Rufat et al., 2015)
		Number of old population and incapable of work			
		Number of handicapped population and incapable of work			
	Occupation (Economic sectors)	Number of employed in primary extractive industries (farming, fishing, mining, and forestry	+	Some occupations are sensitive to any interruptions caused by disasters as they lose their livelihood and financial resources	(Cutter et al., 2003; Rana & Routray, 2018; Rufat et al., 2015)
		Number of employed in transportation, communications, and other public utilities,			
		Number of employed in service occupations			

2.3. Risk assessment

Risk assessment is the initial phase of the risk management process and it forms the scientific base for the decision making in the risk management process. Figure 2-1 illustrates the risk management process. Risk assessment is concerned with investigating and analyzing the consequences of the interaction between hazards and the vulnerability of endangered elements. Thus, risk assessment's primary purpose is to support the decision making to implement proper risk reduction measures and to monitor the effectiveness of these decisions. (Greiving & Fleischhauer, 2006; Wamsler, 2014). This subsection presents the commonly used risk assessment approaches, as well as the utilized risk assessment approaches in Egypt.

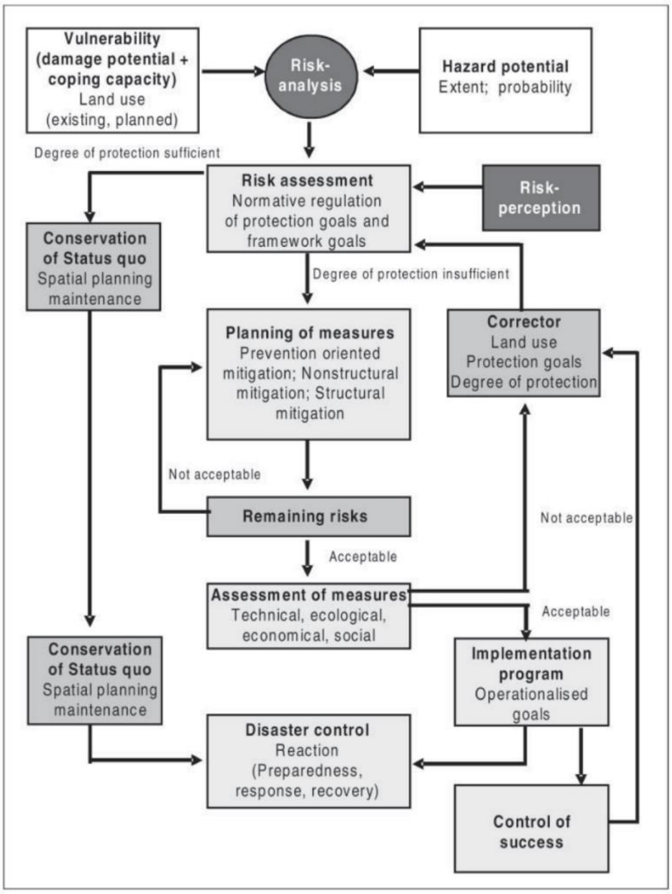


Figure 2-1:The risk management process (Greiving & Fleischhauer, 2006; Wamsler, 2006)

2.3.1. Risk Assessment approaches

There are several approaches for conducting risk assessments that have been adopted by various organizations and researchers. Risk assessments are mainly influenced by the choice of the vulnerability assessment approach, except the risk assessment that utilizes an event tree approach. This subsection will focus on describing four common approaches that show promise in terms of their implementation in spatial planning context (Papathoma-Köhle, 2016; Papathoma-Köhle et al., 2017; van Westen & Greiving, 2017). Figure 2-2 represents an illustration for the risk assessment approaches.

2.3.1.1. **Event tree approaches**

This approach considers the interrelation between different hazards, in particular the chain events which occur when one hazardous event leads to another. Therefore, it utilizes the event tree method in order to objectively assess hazard and risk, as well as identify the most critical sequence of events. The event tree analysis represents the chain system graphically as branches of a tree. Accordingly, the base represents the initial event that triggers other events, whereas the subsequent events are represented as branches. The probability of each consequence's (branch) occurrence is assigned to it based on statistical observations and consensus among experts. Thus, the structure of the tree requires technical judgment from different disciplines to construct a proper sequence of events, as each subsequent branch resembles a particular series of a possible sequence of events. Therefore, multiplying all the assigned probabilities to all the branches that compose a particular series will result in the risk value for this series. However, this approach is considered as problematic because it is demanding for enormous data to determine each event probability (Lacasse et al., 2008; van Westen & Greiving, 2017).

2.3.1.2. **Risk curves (quantitative approach)**

Statistical data and empirical studies are used to extract a function between the asset's physical characteristics (vulnerability) and the hazard intensity. The function is known as the vulnerability curve, and it is represented as a continuous curve. Any point on that curve presents the percentage of loss that this asset would receive corresponding to its vulnerability and the hazard intensity. Since hazard intensities are associated with the hazard's annual probabilities (frequencies), the loss that any exposed asset might receive annually is a result of aggregating the probable losses from the different events with different return periods. Thus, the calculation is repeated for different return periods, and the loss for each return period is then plotted against its temporal probability, which results in a risk curve. Hence, the area under the curve presents the total annual losses (Papathoma-Köhle, 2016; Papathoma-Köhle et al., 2017; van Westen & Greiving, 2017).

There is a significant amount of uncertainty attached to this approach. For instance, if a building is exposed to different hazard intensities, there are several options, such as assigning the maximum, minimum, or average intensity value for this building in order to estimate the loss value, and this causes variances in the results. Also, the approach holds a noticeable degree of uncertainty owing to the quality of the vulnerability data and hazard modeling. Furthermore, the estimate of the assets' monetary values changes according to the information source (e.g. insurance companies, real estate traders, construction cost per Sq. unit). Thus, the result holds cumulated uncertainties in the risk value (Papathoma-Köhle, 2016; Papathoma-Köhle et al., 2017; van Westen & Greiving, 2017).

2.3.1.3. **Risk matrices approach (qualitative approach)**

Unlike the quantitative approach, this approach utilizes the experts' knowledge and opinion under the lack of sufficient quantitative data. Therefore, the available hazard information (e.g. frequencies, intensities) are classified from the lowest to the highest, and similarly, the possible impacts or consequences. Respectively, both frequencies and impacts classes are compared in a matrix where each combination of their classes represent a certain degree of risk (Jaboyedoff et al., 2014; van Westen & Greiving, 2017).

Moreover, under the availability of further vulnerability information, it can be used to form a matrix that compares hazard intensities to assets' vulnerabilities in classes then defines the corresponding risk degree for each pair of classes (Greiving, 2006). Overall, this approach holds a high degree of uncertainty owing to the existence of subjectivity in defining the classes and differences in opinions among the involved experts. Thus, the quality of the results is highly dependent on the opinions of the involved experts to determine the risk scenarios (Jaboyedoff et al., 2014; van Westen & Greiving, 2017).

2.3.1.4. Indicator-based approach

There are different components that contribute to risk, which could be represented in different mathematical equations - pseudo equations (De León, 2006; Wamsler, 2014). Thus, based on the adopted risk equation, in order to incorporate these components in the risk assessment it is required to develop indicators that express each component in a semi-quantitative approach. For example, vulnerability is affected by social and economic components as well as the physical component; therefore, developing indicators that represent each component will result in a holistic perception of vulnerability. These indicators are mostly based on quantitative data such as population census, which could be acquired for different levels of administrative units; however, the final result will only be a normalized risk index that only represents the degree of risk. Nevertheless, this approach offers the opportunity for comparing risk for different areas on different administrative levels (Abella & Van Westen, 2007; Papathoma-Köhle et al., 2017).

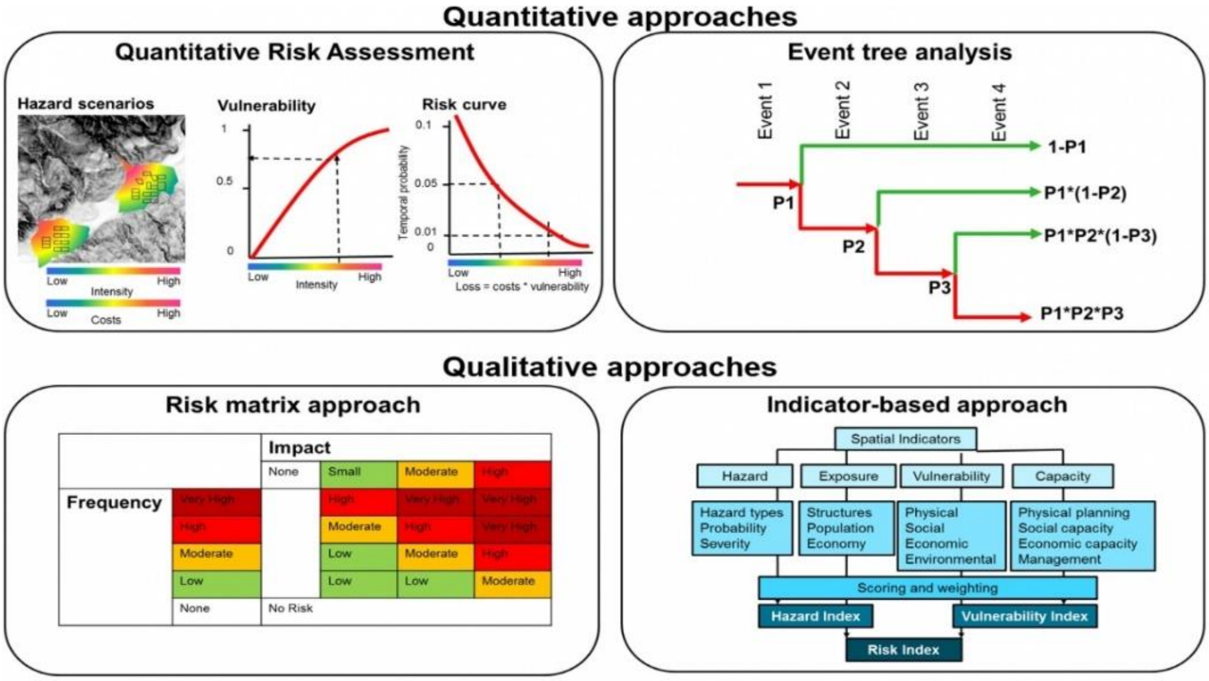


Figure 2-2: An illustration for the risk assessment approaches (van Westen & Greiving, 2017)

2.3.2. Risk assessment practices in Egypt.

Few risk assessment studies were conducted in Egypt, which covers major regions or cities, and mostly, they target one individual hazard. These studies followed either the risk matrix approach or the indicator-based approach to conduct the risk assessment. Several studies cover a tsunami hazard for Alexandria city. It is noticeable that there is a usual focus on the physical dimension of vulnerability. On the other hand, fewer studies focus on other hazards such as the sea-level rise and urban flooding. This section presents a brief description for most of the conducted risk assessment studies for hydrological hazards in Alexandria, Egypt (e.g. tsunami, sea-level rise, flood).

2.3.2.1. Tsunamis risk assessment

El-Barmelgy (2014) and Eckert, Jelinek, Zeug and Krausmann (2012) conducted risk assessment studies for a tsunami hazard in Alexandria. Though El-Barmelgy's work was based on that of Eckert et al. (2012) there are similarities, as well as differences between the two studies, thus, both will be presented. The two studies followed the risk matrix approach; accordingly, Eckert et al. and El-Barmelgy utilized the tsunami inundation depth to present the hazard intensity, which was classified based on the inundation depth danger from the lowest to the highest. Both El-Barmelgy and Eckert et al. applied pre-decided scenarios for the hazard assessment, which is known as scenario-based or deterministic approaches. Consequently, different run-up heights scenarios were simulated based on the historical review of the recorded tsunami events in the Mediterranean. Accordingly, Eckert et al. modelled the inundations that result from tsunami scenarios of 5m and 9m run-up height, while El-Barmelgy added a third scenario with a run-up high of 20m.

There is an emphasis on the importance of including variables that assess other dimensions of vulnerability, such as the socio-economic dimension (Eckert et al., 2012). However, El-Barmelgy (2014) and Eckert et al. (2012) focus was to evaluate tsunami's risk based on physical vulnerability, owing to the lack of qualitative data for small spatial units (e.g. population census) that could be used to evaluate other vulnerability dimensions. El-Barmelgy utilized a GIS database that covers the entire city that was acquired from the General Organization of Physical Planning (GOPP) in Egypt and a limited coarse population data from the 2006 census that was provided by Central Agency for Public Mobilization and Statistics (CAPMAS). Eckert et al., on the other hand, utilized commercial high-resolution satellite images to extract the needed information for estimating physical vulnerability. The extracted information at Eckert et al. study has been validated by samples from a field survey. Therefore, due to the high cost of obtaining commercial satellite images, Eckert et al. risk assessment only covered parts of the city, while El-Barmelgy risk assessment is more inclusive and covers the entire city. Accordingly, Eckert et al. used variables such as 1) building structures, 2) building heights, 3) the number of floors and 4) distance from the shoreline. In addition to the previously mentioned variables, El-Barmelgy used 5) building conditions and 6) land- prices. These variables were used to classify vulnerability into 5 classes in both studies; the classification was based on literature and the authors' judgment.

Both El-Barmelgy (2014) and Eckert et al. (2012) used the risk equation model "Risk = Hazard * Vulnerability". Utilizing the risk matrix approach resulted in 5 classes of risk by Eckert et al. and 6 classes by El-Barmelgy to include the safe areas. Each building was associated with the risk class that corresponds with its vulnerability class and the hazard intensity class, to which it is exposed. Moreover, the risk was estimated for each of the chosen tsunami's run-up height scenarios. Furthermore, both studies quantified the number of buildings in each risk class for the simulated tsunami scenarios. Additionally, El-Barmelgy quantified the monetary loss of the exposed buildings based on the construction price value in Egypt in 2013, as well as an estimation for the exposed population based on the 2006 census on the district's administrative level. El-Barmelgy estimations covered the applied scenarios and classes of risk.

Another study used mixed approaches to conduct the tsunami risk assessment in Alexandria as it utilized both the indicator-based and the risk matrix approaches (El-Hattab et al., 2018b). The indicator-based approach was used to develop the overall vulnerability index, while the risk matrix was used to calculate risk by comparing the vulnerability classes to the intensity classes of the tsunami hazard. Accordingly, El-Hattab et al. (2018) study used the indicator-based approach to assess the different dimensions of vulnerability so that it considers physical, social and economic vulnerabilities. These vulnerabilities were aggregated to provide a total vulnerability index. Furthermore, the authors developed a resilience index using a group of social and economic indicators. Thus, the overall vulnerability index was generated by combining the total vulnerability index with the resilience index.

El-Hattab et al. (2018) utilized data from different sources to develop the used indicators. These data sources mainly included buildings' information and population census on the district's administrative level. The values of each indicator were divided into integer ranks from 1 to 5, as 1 is the lowest value and 5 is the highest value, while the developed resilience index was normalized. Even though, El-Hattab et al. estimated risk based on the equation "Risk = hazard * vulnerability /resilience", the risk was evaluated by using the risk matrix approach based on the matrix introduced by El-Barmelgy (2014).

The work of Eckert et al. (2012), El-Barmelgy (2014) and El-Hattab et al. (2018) exemplify the general practices of the risk assessment studies in Egypt. According to the emphasis from Eckert et al. (2012) on the need for considering the multidimensional aspects of vulnerability, El-Hattab et al. (2018) provide a more realistic perception of risk, thought El-Hattab et al. only focused on quantifying the potential damage to buildings. On the other hand, El-Barmelgy assessment was to support the planning decision making. Therefore, he included estimation of the endangered area, building counts, human casualties, and monetary losses from different tsunami scenarios, which provided a base for prioritizing interventions in planning (El-Barmelgy & Sebaway, 2017).

2.3.2.2. Sea-level rise risk assessment

Alexandria is highly exposed to sea level risk (Kloos & Baumert, 2015; Wöppelmann et al., 2013). Mohammed (2017) conducted a risk assessment study for the potential sea-level rise in Alexandria. Although the study utilized a similar approach as El-Hattab et al. (2018), the author developed different indicators to assess the areas with the potential to be submerged, as well as relevant vulnerability aspects; respectively, the risk matrix approach was used to estimate risk. (Mohammed, 2017)

2.3.2.3. Pluvial flood risk assessment

Though flood is the most frequent natural hazard worldwide and in Egypt particularly, there is no sufficient literature that investigates its posed risk on the Egyptian communities. However, El-Boshy et al. (2019) conducted a pluvial risk assessment study in Alexandria. The authors owe flooding events to the infrastructure failure in disposing of rainwater, especially under extreme burst; such failure usually occurs in developing countries (Pescaroli & Alexander, as cited in El-Boshy et al., 2019). The conducted study consists of three main steps 1) flood hazard assessment, 2) vulnerability assessment 3) institutional response capacity. These steps resulted in a normalized risk index.

El-Boshy et al. (2019) presented the hazard as the value of flood depth in the aftermath of an extreme rainfall event in Alexandria on the 4^{th} of November 2015. Hazard was simulated on an hourly bases using a water run-off model named WDPM that has been provided by the Centre of Hydrology at the University of Saskatchewan in Canada. Furthermore, the study followed the indicator-based approach to incorporate the different dimensions of vulnerability. Thus, the conducted vulnerability assessment considers the physical, social, and institutional aspects accordingly. The indicators were selected based on literature and consultation with experts. Furthermore, a weighting scheme was applied to the indicators to consider the relative importance of the indicators over each other. Additionally, the Response Capacity Index (RCI) was estimated based on the equation "RCI = (ASR/AAT) + (RSR/RAT)", where AAT is the ambulance arriving time, RAT is the rescue arriving time, ASR is the ambulance services ratio, and RSR is the rescue service ratio. The service ratio refers to the available number of ambulance and rescue vehicles.

El-Boshy et al. (2019) utilized the risk equation "Risk = (Flood level * Building Vulnerability * Social Vulnerability) / Response capacity", however, they used the equation to estimate the hourly risk based on the changes in the flood level each hour from the start of the raining event to its end. Thus, the total risk is estimated by summing the hourly risk values. Finally, the risk values were normalized to provide the total risk index.

2.4. Spatial planning

Spatial planning is concerned with changing a current situation to a desirable future; thus, it operates across different sectors and on different spatial scales. The effect of spatial planning emerges as spatial coordination between activities so that they have suitable distribution, pattern and integration. Accordingly, it determines how space should function through time (Fleischhauer, 2008; GOPP, 2015a; Greiving & Fleischhauer, 2006). According to the traditional planning framework that was illustrated by Greiving & Fleischhauer (2006), spatial planning consists of several phases, the problem analysis phase in mainly responsible for providing the scientific base for the planning decisions.

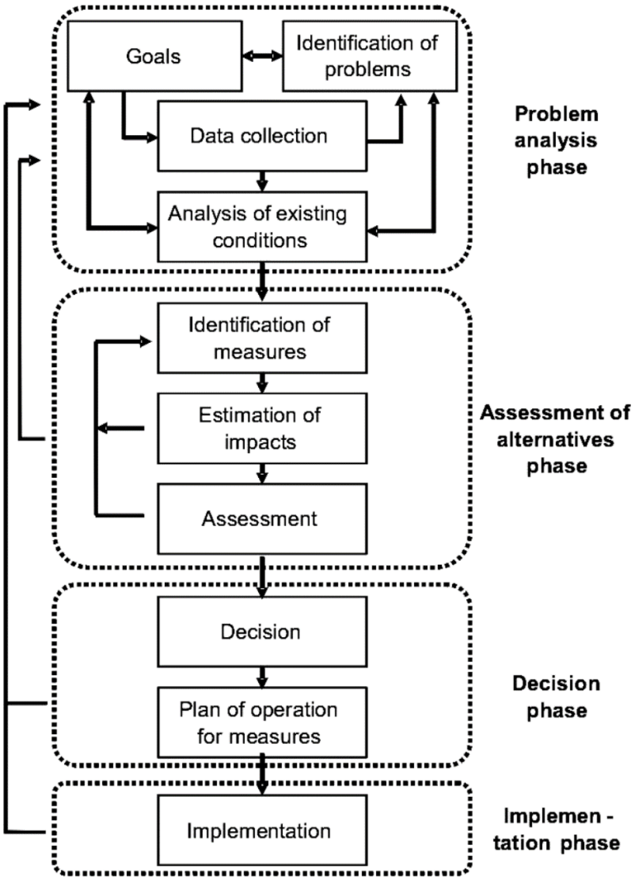


Figure 2-3: The traditional spatial planning process (Greiving and Fleischhauer, 2006)

2.4.1. Spatial Planning role in risk reduction

Urban planning reduces risk by altering the factors that contribute to risk, this could happen by mitigating hazards, eliminating vulnerability and limiting exposure to hazard (Fleischhauer, 2008; Greiving & Fleischhauer, 2006; Herath & Wijesekera, 2019). Therefore, there were attempts to integrate the risk management process with the urban planning process by Greiving and Fleischhauer (2006). Risk reduction is the main goal of the risk management process; thus, for effective integration of both processes, the authors emphasize on the importance of including risk reduction in the earlier stages of planning to start with the identification of planning goals (Fleischhauer, 2008; Greiving & Fleischhauer, 2006).

Moreover, data collection is a crucial part of the problem analysis phase, which is goal-oriented to avoid unnecessary efforts in its collection. The data that determines the vulnerability condition is a vital input for spatial planning, and it is usually well provided by sectorial planning throughout the different spatial planning phases; thus, utilizing this data will considerably improve the vulnerability assessment to be more comprehensive and considerate to the requirements of spatial planning. Accordingly, early coordination between the risk management process and the spatial planning process is unavoidable for enhancing both spatial planning and risk management (Fleischhauer, 2008; Greiving & Fleischhauer, 2006).

2.4.2. Obstacles of mainstreaming risk assessment in spatial planning

Wamsler (2004) investigate the relationship between spatial planning and disaster risk reduction. Firstly, the author reviewed literature that relates to both fields; secondly, she conducted interviews with experts from both sides. The conducted literature review by Wamsler (2004) revealed that there is no sufficient consideration for spatial planning as a risk reduction tool. Additionally, there is less paid attention to investigate the gap and the relationship between both fields and how planning affects the events of disasters, especially from planners' point of view. On the other hand, the conducted interviews by Wamsler (2004) elaborated the perception of each field to the other; urban planner rarely focus on small-scale disasters, which their collective impact is significant; while, disaster risk experts underestimate the planning role in reducing or increasing the disaster's risk. Generally, there is a misconception about the relations between both fields and the need for their integration. Therefore, spatial planning is vital for risk reduction as a pre-disaster measure, as inadequate planning practices can elevate the risk of the hazard and cause catastrophic consequences (Wamsler, 2004).

Risk reduction is a mutual responsibility between the spatial planning field and risk management field (Wamsler, 2006). There are numerous reasons that hinder cooperation between both fields, which were investigated by Wamsler (2006). The author's reasons are based on conducted interviews with experts from both sides. Accordingly, the author concluded that the lack of cooperation and coordination is owing to the differences in the academic background, as both fields do not perceive the effects of their work on the other side, whether they were positive or negative effects; especially, urban planners who do not perceive risk reduction as one of their activities or goals. Nevertheless, urban planning attempts to address risk reduction are usually restrained due to political, institutional and financial constraints. Furthermore, each side lacks the understanding for the other side work; as both sides work with different priorities, terminologies and tools. Spatial planners tend to overlook non-structural and small-scale practices in planning that aim at reducing risk (Wamsler, 2006). Additionally, the institutional framework that each side operates under is completely separate from the other.

2.4.3. The relation between spatial planning in Egypt and the risk reduction

There is a group of laws, regulations and guidelines that organize the spatial planning process in Egypt the primary reference is the Building Law No.119 in 2008. The law states several governing aspects of the spatial planning that includes the type, scales and timeframe. Additionally, the law specifies the responsible authorities for conducting each type of planning (e.g. strategic, detailed) and on each planning level (e.g. local, regional, national). Also, the law state general planning norms with respect to the requirements of different activities. Strategic planning is mainly the responsibility of the General Organization of Physical planning (GOPP), the responsibility of GOPP includes hiring experts, facilitating their work and providing the required data; but most importantly GOPP issues the guidelines and TORs that identify the spatial planning process and outputs (GOPP, 2015b). Based on reviewing the abovementioned law, and samples of guidelines and TORs, as well as the published reports of planning projects by GOPP it is evident that there are no sufficient reflection of risk reduction on the planning outputs in Egypt owing to the current practices' framework.

There are two main types of planning specified in the law, and these types are strategic planning and detailed planning. Strategic planning is usually conducted by GOPP and it covers all spatial levels and corresponding with most of the administrative levels, thus, it covers from the national scale to the local scale- on the level of the city or the village. Furthermore, the detailed planning is mainly concerned with local scale, which starts from the level of a city or a village and down to the smallest feasible scales. Detailed planning is usually conducted by the governorates' planning units. Mainly, the distribution of activities is decided by the strategic planning, and thus, the strategic planning represents the optimal type of planning for considering risk reduction on different planning scales. Accordingly, it is suitable for mainstreaming risk assessment to it (Fleischhauer, 2008; Greiving & Fleischhauer, 2006; Khalifa, 2012; Moustafa, 2015). Figure 2-4 illustrates the corresponding planning types for each administrative level, the ticks in the figure present the obliged plans according to the Building Law No.119 in 2008.

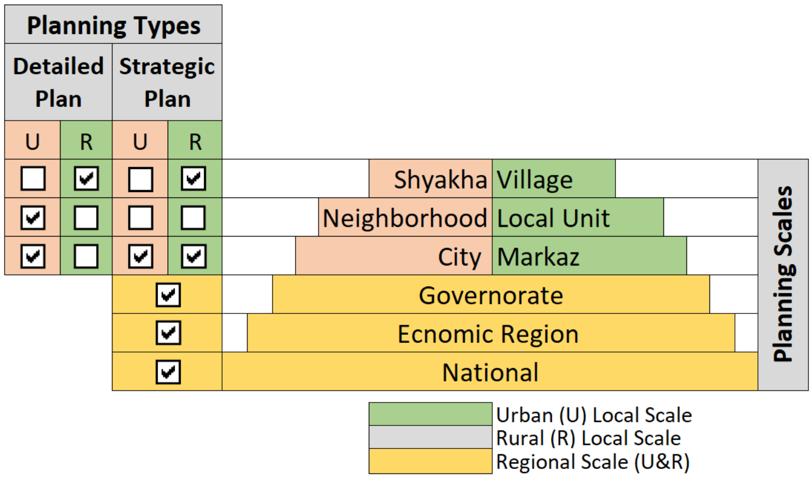


Figure 2-4: The corresponding planning types for each administrative level, the ticks present the obliged plans according to the Building Law No.119 in 2008

2.5. The mainstreaming concept

2.5.1. Definition of mainstreaming

The concept of risk reduction mainstreaming has been associated with urban development and planning since the world's conference on disaster risk reduction in 2005. Mainstreaming can be recognized as a specific way of incorporating a new aspect or goal with the core work of an existing entity without the need to conduct overall changes in the core work of the entity, except for the needed changes that allow the entity to take into consideration the new aspect and eventually it will be reflected on its way of working and its final product. Accordingly, mainstreaming has been explained as conducting the required changes in the institutions in order to incorporate new aspects or methods of work (UNISDR, 2005; Wamsler, 2014; Wamsler & Pauleit, 2016).

2.5.2. Types of mainstreaming

Several mainstreaming strategies have been introduced by Wamsler (2014; 2016) as an outcome of researches since 2003, and the strategies have been constantly developed to match different goals and institutional functions and frameworks. These strategies are based on reviewing and analyzing related studies and projects to risk reduction, as well as the expertise of different institutions that operate in risk reduction. Accordingly, 7 mainstreaming strategies were defined, of which have been implemented in order to mainstream new goals such as risk reduction, climate adaptation and ecosystem conservation into various institutions' policies, programs, plans and projects. These institutions operate in housing, planning, development and emergency aid. Moreover, these strategies can be implemented separately or combined depending on goals and involved institutions, whilst they support horizontal and/or vertical integration. Additionally, 5 measures of risk reduction have been attached to these strategies. These measures include (a) prevention, (b) mitigation, (c) preparedness, (d) risk 'financing', and (e) stand-by for recovery. Consequently, they can be applied for both pre- and post-disaster contexts, also, can work on different institutional levels and scales, as well as different geographical contexts (Wamsler, 2007; Wamsler et al., 2020; Wamsler & Pauleit, 2016).

2.5.3. Importance of mainstreaming

Risk reduction is a cross-cutting task among several sectorial authorities and agencies such as utility provision, water management, environmental protection, shoreline protection etc. Though their measures could be compatible, it also could be conflicting and leads to escalating risk (Greiving & Fleischhauer, 2006; Wamsler, 2014). Even though spatial planning is mainly a responsibility of one authority, plans are being conducted in coordination with several sectorial authorities. Thus, the responsibility of spatial planning is to comprehensively integrate different sectorial plans and disentangle conflicts between their proposed measures; consequently, a plan should reflect other authorities' measures of risk reduction as well as the spatial planning measures for risk reduction (Greiving & Fleischhauer, 2006; Wamsler, 2014). Moreover, spatial planning depends on several authorities to support its general works by providing the needed information for planning. Accordingly, further considerations for risk reduction will require extra support from authorities that can provide risk-related information (Greiving & Fleischhauer, 2006; Wamsler, 2014).

However, mainstreaming risk reduction into spatial planning should clarify the connections between risk reduction relevant authorities either as information sources or as risk reduction actors. Thus, mainstreaming strategies provide the planning authority with different options, activities and actions of which risk reduction can be coordinated with and integrated into its work (Greiving & Fleischhauer, 2006; Wamsler, 2014). Table 2-3 summarizes the mainstreaming strategies and activities for integrating risk reduction and climate adaptation into organizational work. Furthermore, coordinating risk reduction through the spatial planning procedures should harmonize the process of hazards and risk mapping to increase the quality, integrability and comparability of the risk-related information (Greiving & Fleischhauer, 2006; Wamsler, 2014).

Table 2-3: Mainstreaming strategies and associated (Wamsler, 2014; Wamsler & Pauleit, 2016)

Focus of change	Strategies		Activities
Activities at the local program level	(1) Add-on mainstreaming	H[1]/ V[2]	It requires the creation of an entirely new entity that is separate from or under the existing organization; the new entity will be directly responsible for achieving the new goal.
	(2) Programmatic mainstreaming	H	This requires the organization to change its core work to include the new goal among its other goals, which will be reflected on the organization's final product in terms of programs and projects.
Organizational mainstreaming - organizational functioning of implementing bodies	(3) Managerial mainstreaming	H	This will require internal changes in the institutional framework in terms of management, job descriptions of the personal assets, as well as the formal and informal working norms and institutional regulation; thus, the new goal will be institutionalized.
	(4) Regulatory mainstreaming	V	This will require changes in the adopted frameworks' methods, tools and procedures, which are related to the type of work that the organization produces so that the new goal will become part of the daily practices that include legislation, policies and regulation.
	(5) Intra-organizational mainstreaming (**internal mainstreaming**)	V	This requires an internal (vertical) cooperation between the departments and the sectors of the organization, which operate on different scales, levels, and specialties. Also, it includes cooperation with other related entities, as well as the responsibility of the organization to reduce its impact and risk.
Organizational mainstreaming - collaboration and capacity development to influence (urban) sector work in general	(6) Inter-organizational mainstreaming (**external mainstreaming**)	H	This promoting for horizontal integration between different organizations, institutions, and stakeholders to support each other work in terms of exchanging data, information, and studies, as well as joining effort with respect to avoiding efforts duplication.

[1] External and horizontal integration between different organizations in terms of joint efforts and data sharing
[2] Internal and vertical integration between the organization's department that operate on different scales

Interorganizational collaboration and capacity development to influence (urban) sector work in general and education of related professionals in particular	(7) Directed mainstreaming (**educational mainstreaming**)	H/V	This strategy works as a support to the other strategies and the changes that follow them; thus, it focuses on capacity development that includes education, training, funding, promotion, etc.

2.6. Missing links between spatial planning and risk management

The risk assessment phase in the risk management process and the problem analysis phase in the planning process compose the scientific basis for the decision-making process (Greiving & Fleischhauer, 2006). Mainstreaming risk assessment in the planning process will provide planners with the appropriate tool to analyze and understand risk, and thus, adequately reflect risk reduction measures in the planning outputs. The consideration of risk reduction should be initiated from the start of the planning process; thus, it would be embedded in identifying the planning goals, problems and priorities (Greiving & Fleischhauer, 2006; Wamsler, 2014).

Since, vulnerability information is well known and provided for the spatial planning, utilizing the available data sources for spatial planning as an input for the vulnerability assessment will improve it considerably. Additionally, it will enable the assessment to include multiple dimensions of vulnerability (Greiving & Fleischhauer, 2006; Wamsler, 2014). Furthermore, owing to the scarcity of the hazard information for the planning process, cooperation between the spatial planning authorities and the risk management authorities will ensure the provision of the information, as well as consistency in producing the hazard mapping and data. Figure 2-5 illustrates the Missing links between spatial planning and risk management according to Greiving & Fleischhauer and Wamsler (2006; 2014).

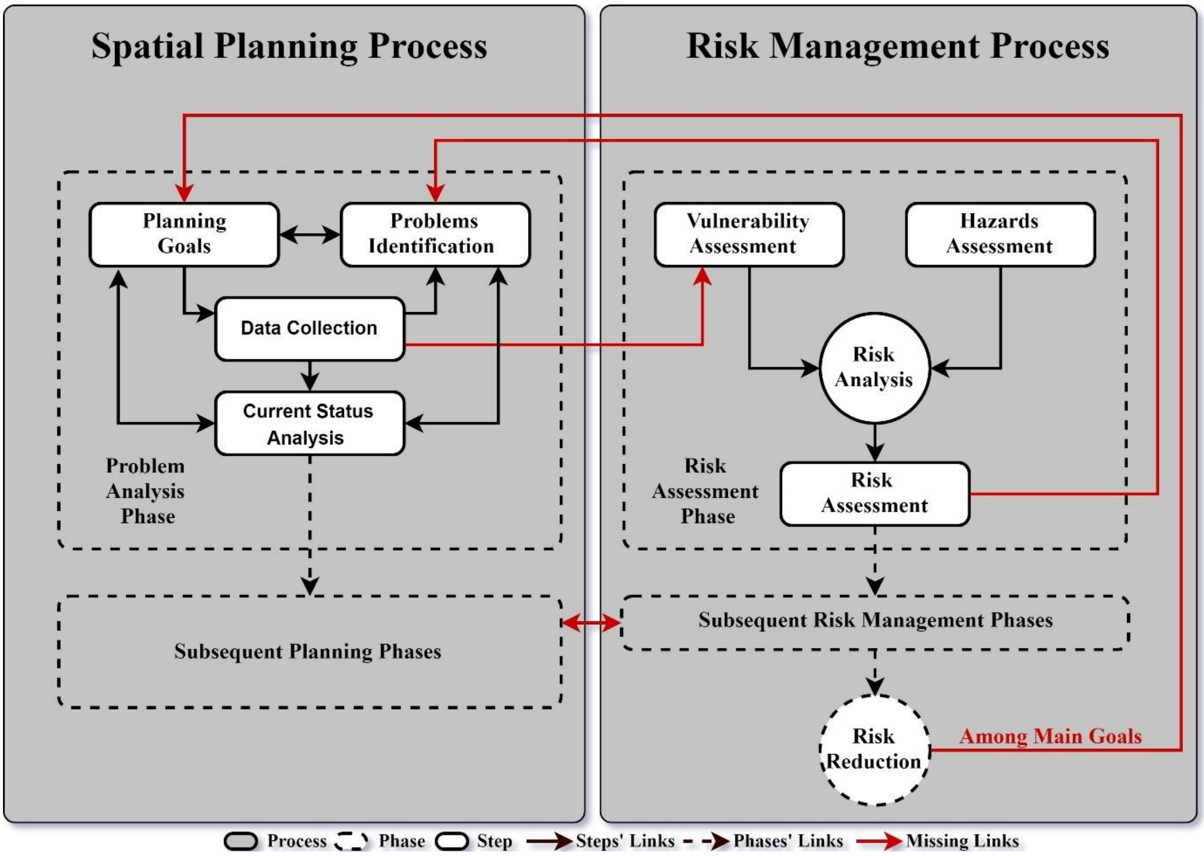


Figure 2-5: Missing links between spatial planning and risk management (Adapted from Greiving and Fleischhauer, 2006 and Wamsler, 2014)

3. STUDY AREA AND METHODS

This chapter starts with describing the study area in Alexandria city, followed by an explanation of the data collection and preparation process. Finally, it illustrates the followed methods to answer the research questions.

3.1. Study area profile

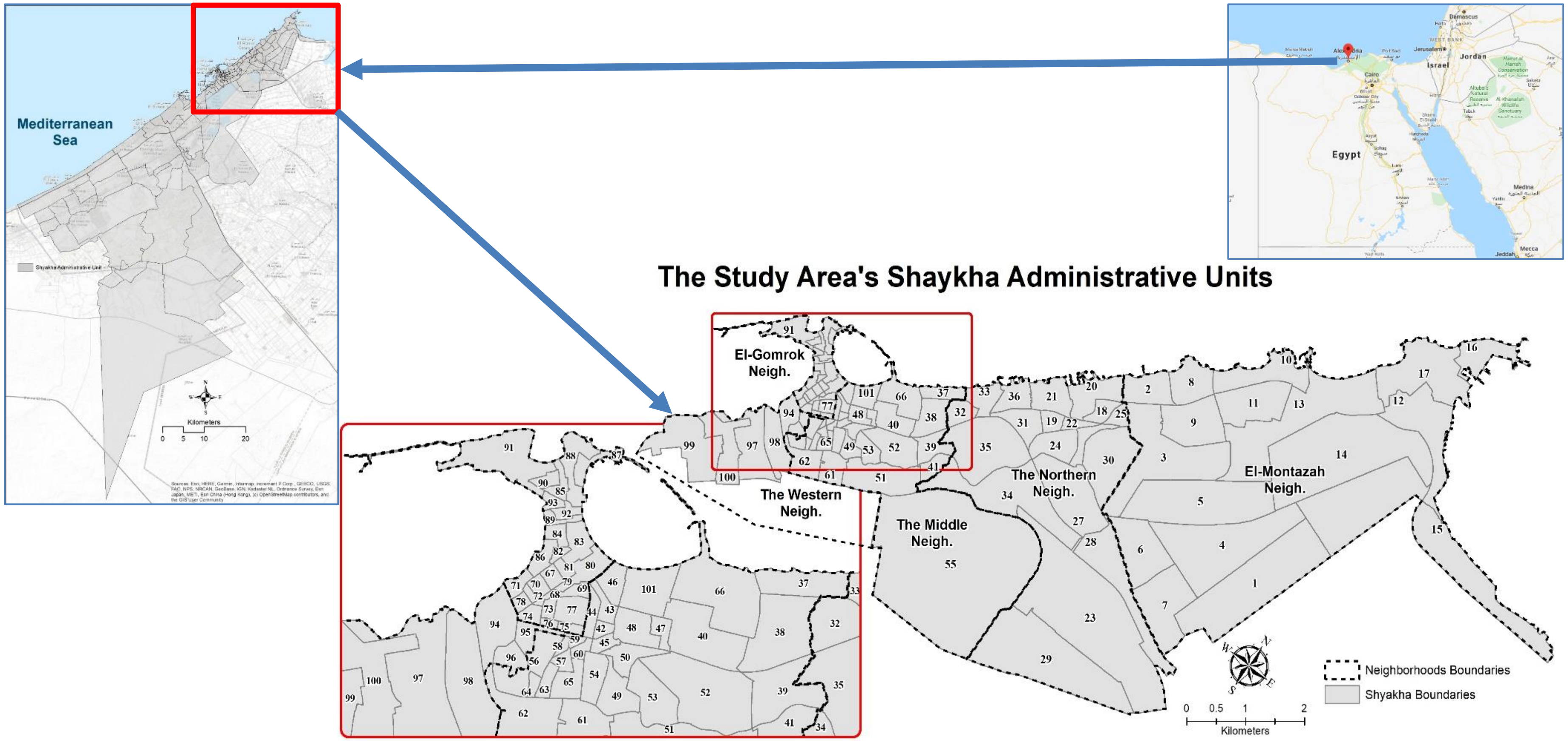
Alexandria's location by the coast and its topographic features increase its susceptibility to urban flood hazards, while its urban and socio-economic status elevates its vulnerability and exposure to the hazard (World Bank, 2011b). The city is the second biggest city in Egypt after the capital of Cairo. It locates in northern Egypt and by the Mediterranean Sea. It is populated with 5.1 million inhabitants (CAPMAS, 2017) and it is projected to range between 6.5 to 6.8 million by 2030 (World Bank, 2011b). The city's area is around 2.818 Km2 (CAPMAS, 2017), it consists of 8 neighborhoods as follows: El-Montazah, the Northern, the Middle, the Western, El-Gomrok, Borg El-Arab, El-Marriout and El-Mex (Alexandria Governorate, 2019). Figure 3-1shows the city location, the Shyakha administrative units and the neighborhoods.

The city has grown along the Mediterranean sea, forming a linear pattern, its natural growth tends to be towards the west; part of the city's growth is informal, moreover, most of the city's agglomeration is along the coastal line. Originally, the city was built over a relatively high coastal ridge that locates between the sea and Lake Maryut that constrains the city from the south. The lake is surrounded with wetlands and cultivation lands, of which both are partially below the sea level (Bigio, 2009; World Bank, 2011b). Floods are the most frequent hazard that occurs in Alexandria; the floods are being triggered by extreme rainfalls and correspond to climate changes' impacts. Thus, its intensity and probability aggravate with time. Alexandria, Egypt is one of the cities that is highly exposed to pluvial urban flood owing to its rapid growth and population density (World Bank, 2011b).

Urban flood events in Alexandria have caused severe damages and losses. The city has shown lack of resilience in facing several events (El-Boshy et al., 2019; Zevenbergen et al., 2017). Alexandria faced its worst flooding events on the 25th of October and the 4th of November in 2015; nearly 60% of the city was flooded. The flood inundation ranged from 0.5m to 1.0m, lowland areas were remained affected up to 15 days. These flooding events happened due to heavy rainfall with nearly 32mm, and were described as rare and historically significant (Bhattacharya et al., 2018; Zevenbergen et al., 2017). A recent study in 2019 has investigated the extreme rainfall events, which caused urban flooding and the losses caused by these events, see Table 3-1 below (El-Boshy et al., 2019).

Table 3-1: Recorded hazard events in Alexandria (El-Boshy et al., 2019)

Date	Rainfall height	Rainfall duration	Economic loss	Human loss
Dec 31, 1991	74 mm	N/A	N/A	80 died
January 26, 2004	N/A	N/A	N/A	N/A
November 30, 2010	180 mm	12 h	N/A	2500 family affected
December 12, 2010	15 mm	9 h	28 building collapse	18 died 11 injured
November 14, 2011	12 mm	9 h	N/A	N/A
September 29, 2015	5 mm	2 h	N/A	N/A
October 25, 2015	53 mm	18 h	9.7 million dollars	13 died 16 injured
November 4, 2015	227 mm	12 h	N/A	N/A



1	El Tawfiqeya	18	El Qasai Bahri	35	Ezbat Saad	52	Ambrooz and Moharam Bek	69 El Genena El Kabira and Souq El Maeez	86	El Belkatria
2	El Seyouf Bahri	19	Zarabanah	36	Mostafa Kamel and Bolokly	53	Bualino and El Eskandrani	70 El Hara El Wasah and El Takhsheba	87	El Sayala Shark and includes - El Sayala 3
3	El Seyouf Qebli and Derbala	20	San Stephano	37	El Ibrahimeya Bahri	54	Ragheb Pasha	71 El Seka El Gidida and El Tartoshi	88	El Sayala Gharb and includes - El Sayala 4
4	El Kerdahi	21	Fleming	38	El Ibrahimeya Qebli and El Hadra Bahri	55	Abis 7-8-12	72 El Saboura	89	El Madoura
5	El Mansheya El Bahria	22	Bakoos	39	El Hadra Qebli	56	El Kara,El Tobgeya and Kafr El Ghates	73 El Naga El Gidid	90	El-Sayadeen
6	El Mohagreen	23	Abis EL Thania	40	Bab Sharki and Waboor El Myah	57	Bab Sedra El Barani Shark	74 El Naga El Qidim	91	Raas El Teen
7	Khurshid El Bahria	24	El Zaheria	41	Ezbat El Gamea	58	Bab Sedra El Barani Gharb	75 Bab Sidra El Jouanny and Genena	92	El Shamoli
8	Sidi Bishr Bahri	25	El Qasai Qebli	42	El Suri	59	Bab Sedra Bahri includes Souq El Ghanam	76 El Ayoni and El Sconia	93	Safr
9	Sidi Bishr Qebli	26	El Mahrosa	43	El Atarin Shark	60	Gamea Sultan	77 Haret El Farahda	94	El Borsa and includes - Kafr Ashri
10	El Mandara Bahri	27	Hagar El Nawateya	44	El Atarin Gharb	61	Gheat El Enab Shark	78 Souq El Gomaa and El Mounir	95	El Amood - Amood El Sawari
11	El Mandara Qebli	28	Khurshid	45	El Marghani	62	Gheat El Enab Gharb	79 Mashmes El Basal	96	Kom El Shaqafa
12	El Maamora	29	Abis EL Owla	46	El Masala Gharb and Sherif Pasha	63	Karmouz Shark	80 El Mansheya El Kobra	97	El Mafroza
13	El Amrawi	30	Dana	47	Koom El Deka Shark	64	Karmouz Gharb	81 El Hamamil	98	El Qabari Gharb and El Qabari Shark
14	El Nasiriya	31	Abou El Nawateer	48	Koom El Deka Gharb	65	Nobar	82 Souq El Barseem	99	Om kebeba - El Metras
15	Tolmbat El Tabiah	32	El Reyada	49	El Bab El Gidid Sharki	66	El Azareta and El Shatbi	83 El Magharba and Souq El Tourk	100	El Wardian
16	Abou Qir El Sharkia	33	Sidi Gaber	50	El Bab El Gidid Gharb and Monsha	67	El Godod and El Laban	84 Abou Shosha	101	El Masala Shark
17	Abou Qir El Gharbia	34	Ezbat El Nozha	51	El Sobheya,Ezbat Sharkas and Ezbat Raafat	68	El Genena El Saghira and Koom Bakeer	85 El Baraka and includes - El Baraka and El Hegazy		

Figure 3-1: The location of Alexandria city, its Shaykha administrative units, and the neighborhood divisions

3.2. Research data

3.2.1. Data collection

Both primary and secondary data were collected to achieve the objectives and answer the questions of this research. Accordingly, the process of data collection and preparation is presented in this sub-section.

3.2.1.1. Primary data

The questionnaire construction

Based on the literature, several deficiencies hinder risk reduction considerations in the spatial planning practices in general. Literature has associated these deficiencies to several reasons including: 1) misperception about the spatial planning role in risk reduction, 2) shortcomings either in data or methods, 3) institutional, procedural, and operational problems, as well as 4) ineffective communication between relevant parties (Greiving & Fleischhauer, 2006; Wamsler, 2006, 2014). Thus, in the context of spatial planning in Egypt, necessities have emerged to develop a better understanding for the following: 1) the extent of considering risk reduction in the spatial planning, 2) the role of risk assessment in supporting risk consideration in the spatial planning, and 3) the reasons behind these deficiencies and the means to overcome them. Therefore, a questionnaire was constructed mainly for the spatial planning experts in Egypt to describe the current relations between natural hazards risk assessment and spatial planning practices in Egypt.

Accordingly, the questionnaire was designed to investigate the three main themes of risk assessment including: 1) hazard 2) vulnerability, and 3) risk. Each of these themes was broken down into 5 essential categories of questions as follows:

1- The perception of the experts to the concept of the theme.
2- The used data and methods.
3- Reasons that hinder the integration of risk assessment into the spatial planning in Egypt.
4- The required improvements to achieve the integration between risk assessment and spatial planning in Egypt.
5- Means of communication's methods, problems, and possible improvements.

Initially, preliminary questions were constructed to be used in semi-structured interviews with two planning experts[3] to make use of their expertise and to get their support in formulating a better tool (questionnaire) to enhance the quality of the data collection process. Accordingly, the experts' comments were used to adjust the questions and construct a more comprehensive online questionnaire. The questionnaire included open-ended questions as well as close-ended questions to apply both qualitative and quantitative analysis on the results.

The dissemination of the questionnaire

The online questionnaire was constructed using "SurveyMonkey" platform, as it facilitated the process of constructing the questions in suitable forms and provided diverse means to disseminate the questionnaire such as e-mails and social media platforms. Furthermore, it provided preliminary statistical analysis for the results, as well as obtaining the results in common formats for direct preparation in Excel or SPSS. 30 invitations were sent to planning experts in Egypt, 22 have responded and completed the questionnaire. The questionnaire was designed to be completed between 45 to 60 minutes. Additionally, the platform offered the opportunity to complete the questionnaire on multiple sessions and was not limited to one-time access which was preferred as it provided the participants more flexibility to complete the questionnaire according to their time-schedules. Owing to the length of the questionnaire and the considerable efforts needed to

[3] The first interviewee was prof. Hesham El-Barmalgy and the second was prof. Abass El-Zafarany

complete it, as well as the limited knowledge with the English language of some participants, an assist was provided for 5 experts to fill the questionnaire. To overcome such limitation, the questions were translated to Arabic (orally) by the researcher and during the same session he translated the participants' answers by himself to be filled once in English during one session per each participant. However, in these cases, the questionnaire took around two hours to be completed as translation to and from Arabic took considerable time and effort.

3.2.1.2. Secondary data

Data has been acquired from different sources to implement a full semi-quantitative risk assessment that can be informative to the spatial planners in Egypt. The collected data included: 1) the urban flood hazard information2) the information needed to conduct the vulnerability assessment.

Urban flood hazard information

The hazard information was provided specifically for this research by Disaster Prevention Research Institute (DPRI) in Kyoto University, Japan. Accordingly, Rainfall-Runoff-Inundation (RRI) was utilized to model the flood inundation and its extent for the study area. The hazard information was directly used in its ASCII format to map and analyze the hazard.

Vulnerability and risk assessments' data

Most of the conducted risk assessments in the context of Egypt are usually following an indicator-based approach that has been conducted subjectively when it comes to the indicator selection and weights. However, there is a necessity to provide the spatial planner with other methods that utilize an objective approach for selecting and weighting the indicators (Reckien, 2018; Yoon, 2012). Thus, data were collected to apply an inductive approach for the risk assessment using PCA.

Alexandria's census data and the physical features geodatabase were the core of the conducted vulnerability and risk assessments. The required data for both the vulnerability and risk assessments were obtained by direct contact with the relevant authorities. Table 3-2 summarizes the collected data and its metadata. The census of 2017 was obtained in Excel format from the Central Agency for Public Mobilization and Statistics (CAPMAS). Since the population economic conditions are not completed yet for the year of 2017, a geodatabase for the census of 2006 was used to complete the missing information. Furthermore, a detailed geodatabase was provided by The General Organization of Physical Planning (GOPP), which contained the physical features of Alexandria city, including the information of the buildings, roads, and public infrastructure. Additionally, other data sources were utilized to obtain data with potential usefulness, and these data included the locations of schools, hospitals, and historical sites.

Table 3-2: The utilized data for the vulnerability assessment

Data	Information	Source	Format	Scale
Census 2017	Buildings and units physical conditions	Central Agency for Public Mobilization and Statistics (CAPMAS)	Excel	Shyakha administrative units
	Population social conditions			
Census 2006	Population economic conditions		Geodatabase	
The city physical geodatabase	-Buildings information (use-hights-conditions-structure) -Infrastructure (i.e. roads-public networks)	The General Organization of Physical Planning (GOPP)	Geodatabase	Buildings levels
Schools	-Location, type, and number of students	The General Authority for Educational Buildings (GAEB)	Shapefiles	
Hospitals	Location	Ministry of Health		
Historical sites	Location and area	Atlas of Antiquities from Ministry of State of Antiquities		

3.2.2. Data preparation

3.2.2.1. Primary data

Since SurveyMonkey allows downloading the questionnaire data in different formats, Excel compatible format was chosen as the best format to prepare that data. Respectively, answers which are relevant to each question were presented in a separate Excel sheet and then converted to separate text documents. This allowed flexibility in importing and organizing the documents in ALTLAS.ti 8 for qualitative analysis. Accordingly, documents were grouped together based on their affiliation to the themes and the categories.

3.2.2.2. Secondary data

The preparation of the secondary data was challenging for several reasons. First, the collected data is inconsistent in its format. Second, the data required intense preparation using Excel and ArcGIS to harmonize and join it together; especially, the data for census 2017 as it was provided in separate Excel files. Then the relevant variables to each vulnerability dimension were joined in separate Excel files as preparation for SPSS and for conducting PCA.

3.3. Research methods and data analysis

This section describes the followed methodological framework to fulfill the research objectives and answer their related questions. Both qualitative and quantitative methods will be used to implement the research throughout four stages, which correspond to the four objectives, as illustrated in Figure 3-2.

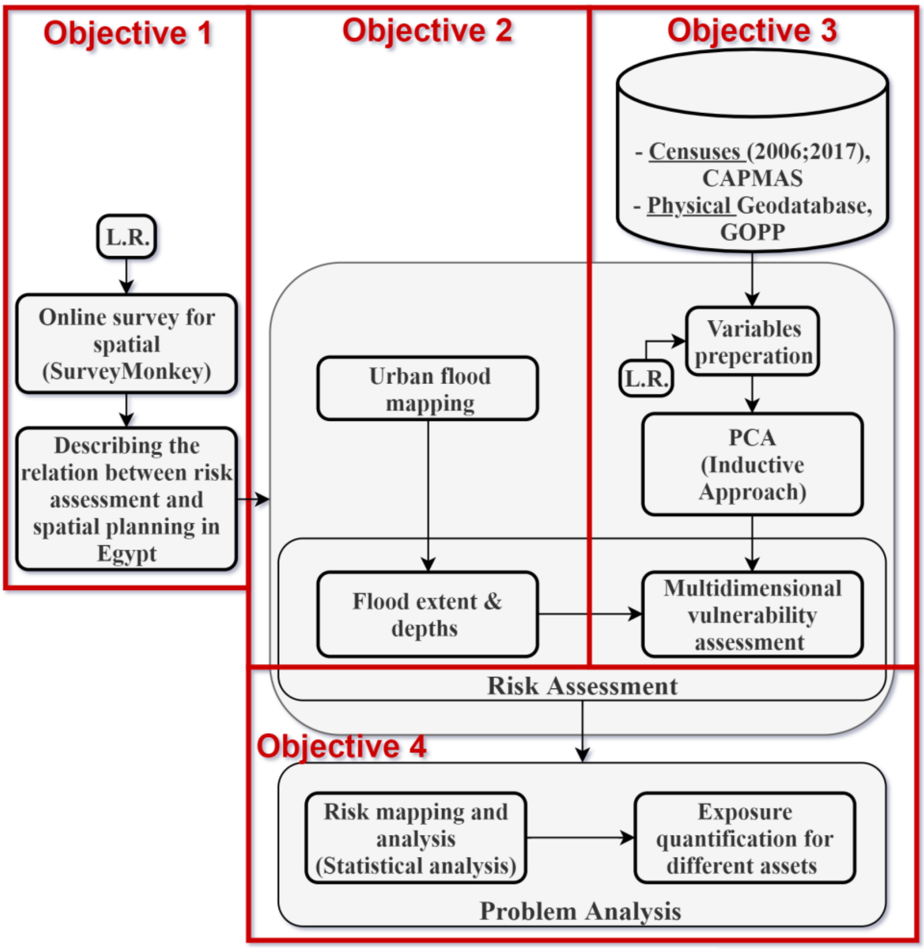


Figure 3-2: The followed methodological framework

3.3.1. Objective 1: Description of the current relations between risk reduction and spatial planning practices in Egypt

Quantitative analysis will be performed for the close-ended questions to measure the frequency of answers selection for each question. Whereas qualitative analysis will be applied as a content analysis on the open-ended questions using "ATLAS.ti 8" software (Erlingsson & Brysiewicz, 2017; Kumar, 2011).Thus, the questionnaire will be divided to three main themes including: 1) hazard 2) vulnerability, and 3) risk. Each of these themes will be broken down into 5 essential categories as follows:

1- The perception of the experts to the concept of the theme.
2- The used data and methods.
3- Reasons that hinder the integration between risk assessment and the spatial planning in Egypt.
4- The required improvements to achieve the integration.
5- Means of communication's methods, problems, and possible improvements.

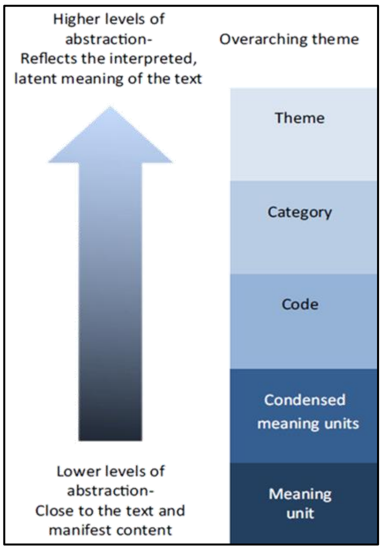


Figure 3-3: The questionnaire content analysis phases by "ATLAS.ti 8" (Erlingsson & Brysiewicz, 2017)

Respectively, the open-ended answers will be condensed by assigning codes to them. Similar codes will be assigned to similar answers, while unique codes will be assigned to outlier responses. Codes frequency analysis by ATLAS.ti 8 will be used to highlight the points of consensus between experts, as well as points of differences and unique responses. Thus, this analysis will be associated with the close-ended answers to provide a comprehensive understanding of the qualitative data, which will be explained accordingly. Figure (3-2) illustrates the structure of the content analysis.

3.3.1.1. The contributions of risk assessments in the current spatial planning practices in Egypt

Mainly, categories number 1 and 2 of the questionnaire were designed to obtain relevant answers that describe the planners' perception towards the different concepts related to risk and to what extent they take risk into consideration in the planning practices.

3.3.1.2. The aspects that enable or disable mainstreaming risk assessment into the spatial planning practices in Egypt

Categories 3, 4 and 5 resulted in a description of the main problems that limit planners from using the risk assessment as an analysis tool for risk reduction in the spatial planning practices in Egypt. Furthermore, the answers provided several potential improvements, which have been proposed by the experts to enhance the integration between risk assessment and spatial planning practices in Egypt.

3.3.2. Objective 2: Map the worst observed event of urban flood in Alexandria, the storm of the 4th of November 2015

The second objective relates to mapping the worst observed urban flood event in Alexandria. In 2015, Alexandria faced two extreme rainfall events that caused severe human and economic losses. The average flood depth ranged between 0.5m and 1m; Rainfall on 25th October 2015 was around 32mm in a short time, which caused flooding (Bhattacharya et al., 2018; Zevenbergen et al., 2017).

The simulation for the urban flood inundation and extent was provided by DPRI in Kyoto University, Japan. The simulation was conducted using an open-source flood model RRI, which requires three main data inputs 1) rainfall data for the simulated event, 2) the study area terrains 3), and the study area landcover (ICHARM, 2020). The simulation was conducted for the 4th of November event utilizing the rainfall data from PERSIANN-Cloud Classification System (PERSIANN-CCS). Furthermore, DEM from ALOS WORLD 3D with 30m resolution was used as the terrain input. The landcover information was obtained by conducting a maximum likelihood classification on Sentinel 2B satellite image by ArcGIS, the image is for the data of November 2015 corresponding to the flooding event date. Finally, the simulation was calibrated by using in situ images, which have been obtained from the online local news. Figure 3-4 illustrates a schematic diagram of RRI model.

The output of the model was provided as an ASCII file, accordingly, it will be used to map the hazard inundation and extent. Zonal statistics will be performed by ArcGIS to obtain the maximum hazard intensity (Inundation depth) per Shaykha unit. Additionally, the hazard intensity variations for Shaykha units will be mapped and classified.

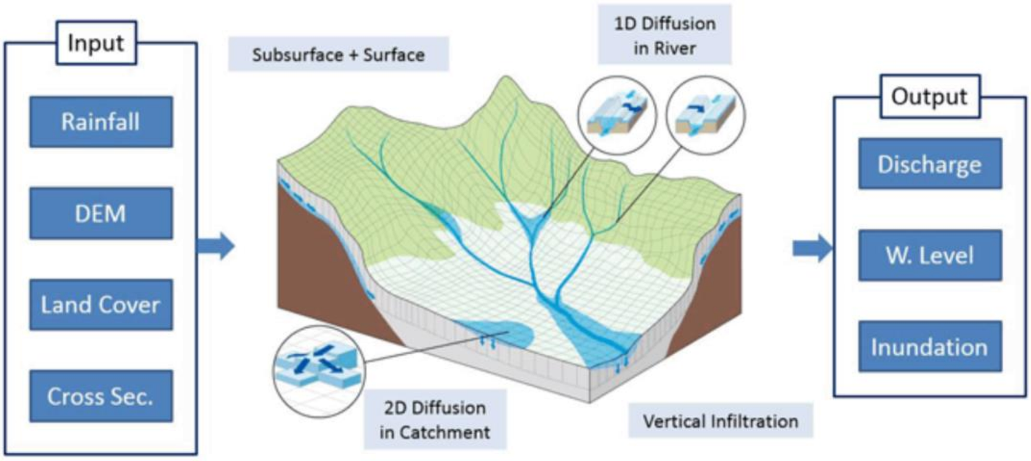


Figure 3-4: schematic diagram of RRI mode (ICHARM, 2020)

3.3.3. Objective 3: Assessing the vulnerability of Alexandria city to urban flood hazard

Most of the conducted risk assessments in the context of Egypt usually followed an indicator-based approach that has been conducted subjectively when it comes to the indicator selection and weighting. However, there is a necessity to provide spatial planners with other methods that utilize objective approaches for selecting and weighting the indicators (Reckien, 2018; Yoon, 2012). This subsection will describe the needed methods to provide an inductive vulnerability assessment using PCA. Thus, the variables selection approach will be demonstrated, as well as the process of using PCA to conduct a multidimensional vulnerability assessment (Török, 2018). Figure 3-5 illustrates the followed method for conducting the vulnerability assessment by PCA, which is adapted from Török (2018).

3.3.3.1. **Indicator selection and vulnerability dimensions**

These objective attempts to provide a multidimensions vulnerability assessment that considers the 1) physical 2) social 3) economic aspects in Alexandria. Thus, indicators will be selected based on the 4 criteria as follows:

1- Literature related to the risk assessment in the Egyptian context
2- Literature related to urban flood vulnerability assessments
3- Questionnaire
4- Available data

The literature review was conducted to investigate the commonly used indicators for assessing vulnerability in urban flood context worldwide. However, the search within the Egyptian context wasn't associated with a specific type of hazard to draw a comprehensive understanding of the risk and vulnerability assessment practices in Egypt. The search was conducted on Scopus and Google scholar databases by using keywords such as: risk, vulnerability, flood, hazard, Egypt, assessment etc.

3.3.3.2. **Implementing the vulnerability assessment using PCA**

PCA will be utilized as an inductive approach to minimize the number of potential variables associated with vulnerability. Accordingly, PCA has a high potential in utilizing rich sources of data in conducting the vulnerability assessment (Reckien, 2018). Thus, the data set that includes all potential variables will be prepared for 101 Shyakha's units. These variables will be constructed based on the obtained census data and the city's physical geodatabase, as well as the other previously mentioned data sources. PCA will be utilized to combine partly correlated variables to smaller uncorrelated components (Reckien, 2018; Török, 2018). Several software packages can be used to conduct PCA, however, for this research SPSS was used for that purpose. This method is based on the work conducted by Cutter et al. (2003) and was followed by many other researchers with interest in assessing social vulnerability (Frigerio & De Amicis, 2016; Reckien, 2018). Figure 3-5 illustrates the process of conducting inductive vulnerability assessment and the utilization of PCA by SPSS.

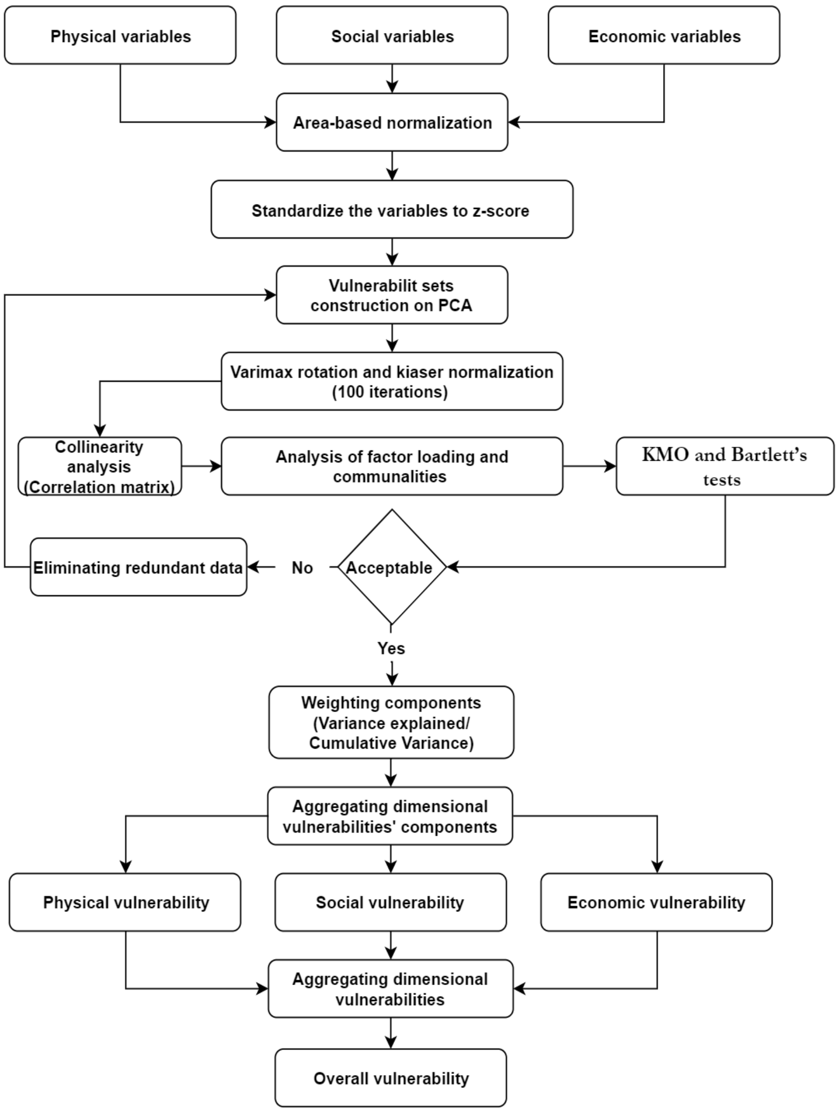


Figure 3-5: The followed method for conducting the vulnerability assessment by PCA (Adapted from Török, 2018)

Furthermore, the vulnerability assessment process will be described systematically as follows:

Normalization
All potential variables will be normalized as an area-based metric (number of assets per Sq. Km.). Since a recent study by Reckien (2018) reveled that area based is preferable over percentage-based metric for more credibility and quality as the high value for an index using area-based data, indicate a higher density of vulnerable assets in comparison to the vulnerability index of percentage-based data (Cutter et al., 2003).

Standardization
Several standardization methods were discussed by Yoon (2012), however, it was argued by Yoon (2012) and Tate (2012) that the standardization method effect is negligible on the final result. However, Z-score method will be utilized as it avoids potential errors resulting from the aggregation of variables with different means (Cutter et al., 2003). This method of standardization converts all variables to a common scale with a mean of zero and a standard deviation of one, as in Equation 3-1.

Equation 3-1: Z-score standardization

$$Z = \frac{Score - Mean}{Standard\ Deviation}$$

Implementing PCA with SPSS
PCA will be performed by SPSS using a varimax rotation (100 iterations) and Kaiser criterion (100 iterations). This rotation reduces the tendency for a variable to load highly on more than one component. This technique minimizes the number of variables that have high loading on a single component and clarifies the interpretation of the component. The number of components will be reduced by omitting components with eigenvalues larger than 1.0 (de Sherbinin & Bardy, 2015; Török, 2018; University of South Carolina HaVRI, 2011; Wood et al., 2010).

Collinearity check
Implementing PCA by SPSS has its own advantages as each attempt can provide a correlation matrix for the utilized set of variables. Thus, highly correlated variables were spotted, and only one was left as a representation for the others. The pairwise correlation test is necessary for the collinearity analysis and the elimination of redundant data, thus, variables with correlations coefficient greater than 0.80 were excluded (Abson et al., 2012; Field, 2013; Török, 2018).

Robustness check
To check the robustness of the model, two statistical tests—the Kaiser-Meyer-Olkin (KMO) for sampling adequacy and Bartlett's Test of Sphericity— will be used. KMO values above 0.6 indicate an acceptable level, while values above 0.8 denote a good compatibility level of variables. Bartlett's test of Sphericity verifies that the utilized variables are suitable for the PCA when $p < 0.01$ (Field, 2013; Török, 2018; Wood et al., 2010).

Commonality and Loadings
Attention will be paid to omit variables that load less than 0.5 and higher than -0.5 in all components. Furthermore, variables with small communality scores (less than 0.3) were also omitted (Field, 2013; Török, 2018; Wood et al., 2010).

Weighting
Respectively, the resulted factor scores for each component will be weighted by the ratio of the component's variance explained to the cumulative variance explained by the dimension's components. Components will be mapped separately using the resulted weighted factor scores. The summation of the weighted components will result in a cumulative vulnerability score for each dimension. Additionally, the cumulative

vulnerability score of each dimension will be used to map its spatial distribution (Abson et al., 2012; Reckien, 2018; Tate, 2012; Yoon, 2012).

Mapping the overall vulnerability

The cumulative vulnerability scores for the three vulnerability dimensions will be added to calculate the overall vulnerability and map it. This method of aggregation is commonly implemented in the vulnerability assessment studies (Frigerio & De Amicis, 2016; Tate, 2012). The map will be classified using standard deviation classes to represent the scores variations from the mean (Török, 2018; Wood et al., 2010). This method of classification aligns with the z-score transformation described earlier; mapping via standard deviations provides a relative representation of which Shyakha unit deviates more from the city's means and does not provide an absolute representation of vulnerability (Wood et al., 2010).

3.3.4. Objective 4: Providing an informative risk assessment for spatial planning

Risk will be estimated by combining the vulnerability and the hazard intensity on the level of Shyakha units using the equation Risk = Hazard * Vulnerability (Wamsler, 2014). First, the resulted Overall vulnerability will be normalized using min-max rescaling to eliminate the negative values and produce vulnerability scores between 0 and 1 (Abson et al., 2012; Reckien, 2018; Yoon, 2012). Equation 3-2 illustrates the used method for normalization. Respectively, the hazard intensity and the normalized overall vulnerability score will be multiplied to produce a risk degree index. Accordingly, risk will be classified using the standard deviation classification and mapped. A statistical comparison between neighborhoods in terms of risk's values in variations will be conducted to demonstrate priorities of attention.

Equation 3-2: Minimum-maximum rescaling

$$Vulnerability\ Score = \frac{Score - \text{Minimum Score}}{\text{maximum Score} - \text{Minimum Score}}$$

4. RESULTS

This section elaborates the findings of the conducted questionnaire with a group of spatial planning experts in Egypt. Annex 1 shows the constructed questionnaire for the experts. The results of the open-ended questions, which have been analyzed by "ATLAS.ti 8" are summarized as bar-charts while the close-ended questions are presented in tables. Annex 2 illustrates the resulted coding scheme using "ATLAS.ti 8". Three main themes were covered by the questionnaire 1) hazard 2) vulnerability and 3) risk. Each of these themes was broken down into 5 essential categories as follows:

1- The perception of the experts to the concept of the theme.
2- The used data and methods.
3- Reasons that hinder the integration with the spatial planning in Egypt.
4- The required improvements to achieve the integration.
5- Means of communication methods, problems, and possible improvements.

4.1. Objective 1: Description of the current relations between flood risk assessment and spatial planning practices in Egypt

4.1.1. Brief about the questionnaire participants

The questionnaire has been taken and completed by 22 out of 30 spatial planning experts in Egypt. The participants consisted of academics and professionals in the field of spatial planning. It is worth mention that, the academic participants also have the professional experience to their backgrounds owing to their involvement in several planning projects in Egypt. The participants have a wide range of experience on the academic as well as professional levels.

4.1.2. Flood hazard assessment practices within the spatial planning process

4.1.2.1. The planner's perception of flood hazard exposure and its effects in Egypt

Experts have mainly associated hazard exposure with the existence of a cause or a source for danger, as 19 experts explained; this danger was described either as environmental (natural) or manmade (artificial) hazards. Assets that are influenced by the hazard impacts were described as endangered elements by 14 experts. The negative impacts of hazards were described as damage or losses, which affect lives, natural resources, livelihoods or physical developments as 11 experts answered. Furthermore, this danger was attributed to spatial and temporal extents by 12 experts, thus, assets that spatially located within the influence of the danger are considered as elements at risk; 2 of the 12 associated the temporal extent with the suddenness, frequencies, and duration of the events. 3 experts stated that hazards' impacts are being affected by its characteristics (type, frequency, and intensity). Also, 2 experts connected the hazard's impact with the vulnerability of the endangered elements. Finally, only 1 response has identified exposure as part of the environmental study in the planning process. Figure 4-1 summarizes the used concepts by the experts to describe hazard exposure.

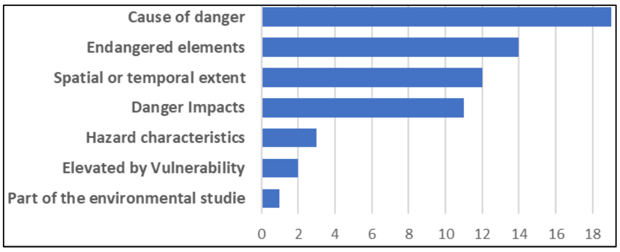


Figure 4-1: The used concepts by the experts to describe hazard exposure

There was no consensus among the experts whether urban flood hazard is being recognized as a major concern in Egypt or not. Nevertheless, answers leaned towards rare recognition, and thus, rare consideration from the spatial Planning side. Table 4-1 shows the variations of the experts' responses regarding urban flood recognition in Egypt.

Table 4-1: The experts' responses regarding urban flood hazards' recognition in Egypt

1) Never	2) Very Rarely	3) Rarely	4) Half the Time	5) Usually	6) Always	Total
1	5	5	4	6	1	22

Aspects that increase the severity of flood hazard in Egypt

Experts have highlighted several aspects that aggravate the severity of flood effects, which have been summarized in Figure 4-2. According to 12 experts stated that inadequate planning practices had increased the impacts of hazards. Furthermore, 1 expert mentioned that population and activities are usually agglomerated on locations near livelihoods, though they could be endangered locations. 2 experts stated that, Egyptian settlements expanded over locations that are susceptible to floods over the years and disregarded the environmental characteristics of these locations. Another, 2 experts connected the increased severity of floods to climate change.

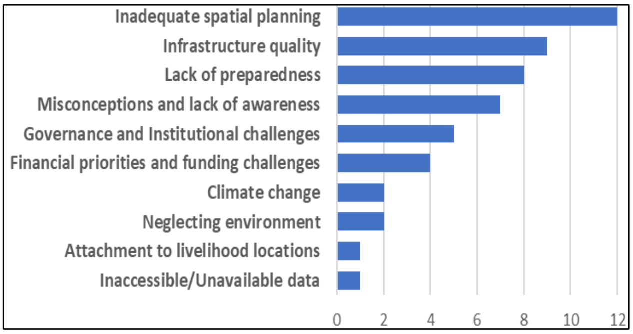


Figure 4-2: The mentioned aspects by experts, which aggravate the severity of flood impacts

Another major contributing factor for the hazard severity is the inadequate infrastructure, which has been mentioned by 9 experts; this has owed to the lack of proper drainage system with the capacity to absorb the excessive increase in surface water. Furthermore, Egypt was attributed to the lack of preparedness for the flood events and the absence of utilizing early warning systems, which was highlighted by 8 experts.

Decision-makers and citizens were attributed to a lack of awareness and misconceptions which were selected by 7 experts, and they owed this to the fact that both parties (decision-makers and citizens) recognize Egypt as safe from floods. According to 5 experts, governance and the institutional framework are not adequately prepared to deal with hazards in an integral approach since relevant institutions usually work in isolation from each other. This has been owed to the lack of communication and integration frameworks, as well as the insufficient support by policies and the planning tools. There is also a financial limitation that hinders the ability of government and citizens alike to apply mitigation measures; thus, funds are usually directed to other aspects which have been considered as a priority over flood hazards' risk reduction, this was expressed by 4 experts. 1 expert expressed that related data to hazard is scarce since data is usually inaccessible or unavailable, especially on the local level scale, which hinders the ability to make decisions regards hazard risk reduction.

Egyptian's regions flood susceptibility

Participants have associated flood hazard to several locations in Egypt, especially, settlements which are adjacent to hilly and mountainous areas. Thus, owing to the rugged nature of the Red Sea coast and on Sinai, the adjacent settlements are highly exposed to flood events; for example, cities such as Ras Ghareb and Ras Shokeir have been frequently hit by floods. On the other hand, the settlements by the Mediterranean Sea coast are also attributed as susceptible to flood owing to their high exposure to frequent rainfalls; thus, cities such as Alexandria and Matrouh have been witnessing several flood events. Another factor that is making Alexandria more vulnerable to urban flooding is its, metropolitan nature which is associated with specific morphological characteristics such as size, densities, pattern, and topography. Nevertheless, rural areas in Upper Egypt were also described as highly susceptible to flooding owing to their poor infrastructure and physical conditions.

4.1.2.2. The commonly used data and methods to acquire the flood hazard information

Planners utilize different data sources to acquire the needed flood hazard information. Table 4-2 illustrates the commonly used data sources to acquire flood hazard information and the degree of their usage. Planners often obtain hazard information from the available literature, studies conducted by specialized institutions (EEAA, EMA, NARSS) or hazard experts. However, hazard experts, including flood modelers are rarely involved in the planning process based on the opinions of 16 out of 22 participants who responded that hazard experts are not usually involved.

Topographic maps are widely and directly used by planners to locate the main streams in the planning area; different scales of topographic maps are used based on the planning scale. However, small scale maps such as 1:25000 are mostly used owing to its availability as smaller and more accurate scales are usually unavailable. Furthermore, open sources DEMs such as SRTM, ASTER and AW3D are used to extract the streams network by using the existing hydrological analysis tools in software such as ArcGIS or QGIS. These tools are perceived as easy to use by planners. Satellite images such as Sentinel, Landsat, MODIS, or Spot were recognized as potential sources for hazard information.

Table 4-2: The commonly used data sources to acquire flood hazard information and the degree of their usage

	1) Never	2) Very Rarely	3) Rarely	4) Half the Time	5) Usually	6) Always	Total
1) Literatures	0	1	1	5	10	5	22
2) Geotechnical maps encyclopedia	1	2	4	2	7	6	22
3) Topographic maps 1: 100,000	2	2	1	8	6	2	21
4) Topographic maps 1: 50,000	1	1	1	5	13	1	22
5) Topographic maps 1: 25,000	0	1	0	4	9	7	21
6) Digital Elevation Models (SRTM) 30m	2	2	3	2	7	6	22
7) Digital Elevation Models (ASTER) 30m	3	2	3	2	6	5	21
8) Digital Elevation Models (ALOS World 3D) 30m	3	3	4	2	5	4	21
9) Satellite Images (Sentinel)	3	3	2	3	4	5	20
10) Satellite Images (LANDSAT)	1	2	3	6	5	5	22
11) Satellite Images (MODIS)	2	3	5	3	3	5	21
12) Satellite Images (SPOT)	3	1	4	2	4	6	20

Participants responded to a question asking about the most hazard information they usually take into consideration. Their answers revealed that the location and the spatial distribution are the most important criteria they use in their assessment followed by the event return period, then the flood depth. Nevertheless, flood streams network information is perceived as necessary while planning for new development, especially in the desert hinterlands. Table 4-3 illustrates the hazard criteria's importance degrees.

Table 4-3: The hazard criteria's importance degrees

	1) Never	2) Very Rarely	3) Rarely	4) Half the Time	5) Usually	6) Always	Total
1) Flood depth	3	4	3	3	8	1	22
2) Spatial distribution (location)	1	1	2	4	10	4	22
3) Frequency	2	5	3	4	5	2	21
4) Return period	1	5	2	4	7	3	22
5) Flood duration	1	5	3	5	6	0	20
6) Flood speed	2	4	8	2	2	2	20

According to 7 out of 9 participants, though flood hazard experts are rarely involved, they mostly provide further information that has been perceived as crucial and sufficient for planners. Accordingly, in addition to the streams network, hazard experts mostly provide hazard assessment study that includes hazard and risk mapping. Also, they provide information such as flood's spatial distribution, depth, frequencies, return period, duration, and flow speed. Furthermore, the hazard experts usually asked by planners to recommend possible interventions to be considered in planning. Thus, hazard experts recommend structural interventions such as dams or culverts possible locations, as well as non-structural interventions such as safety buffers or possible land-uses in hazardous areas. Figure 4-4 illustrates the frequency of the provided information by hazard experts.

Mostly, planning experts are unaware of the used models or software by hazard experts and they only concerned about the output. However, as Figure 4-3 illustrates, participants have specified few software and tools that are used by hazard experts such as hydrological analysis and Arc-Hydro tool sets in ArcGIS; QGIS hydrological analysis; HEC-RAS; and remote sensing.

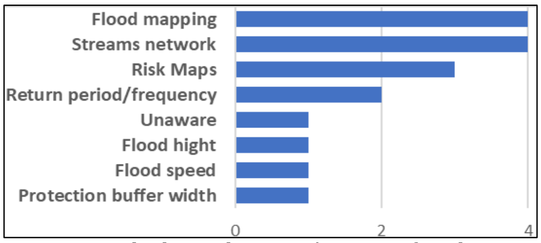


Figure 4-4: The hazard experts' outputs for planners

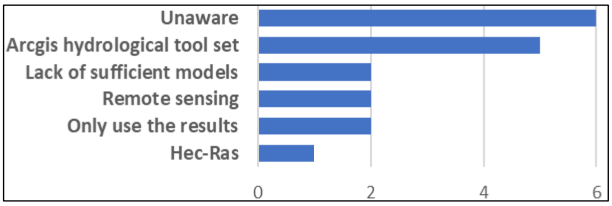


Figure 4-3: Used methods by hazard experts

The sufficiency of the methods

The experts' answers about the extent of the sufficiency of the methods revealed variance in opinions. However, the answers slightly lean towards moderate to high sufficiency. Table 4-4 demonstrates the variance in the experts' opinions regarding the sufficiency of the used data and methods.

Table 4-4: The experts' opinions regarding the sufficiency of the used methods

1) Not Sufficient	2) Low Sufficiency	3) Moderate Sufficiency	4) High Sufficiency	Total
4	6	5	6	21

4.1.2.3. **The communication of flood hazard information**

According to 10 experts, hazard mapping is the commonly used method for communicating the hazard information, 6 experts answered that hazard mapping is mostly provided by specialized institutions such as EEAA, EMA, and NARSS. Based on the participants, though hazard experts are usually absent from the planning team, when they are involved, they provide the information according to the planning team's needs. Hazard information is usually included in the reports issued by the specialized institutions and prepared by hazard experts. Furthermore, the information could be provided in different spatial data formats for flexible usage by planners. In addition to hazard mapping, the provided studies usually include other descriptive, statistical and visualized information.

Individual statements highlighted the following: Planners could use their own experience in estimating hazard throughout the available information. Environmental experts usually substitute the absence of the hazard experts; however, they use literature and experience to describe the environmental status and provide warnings of possible hazards. Since flood hazard is rarely recognized in Egypt by different actors, it is not usually communicated, and thus, neglected. Although planning projects' TORs sometimes require hazard assessment, very few strategic plans include the hazard information and mostly on the regional scale only. Figure 4-5 shows the mentioned means of hazard communication.

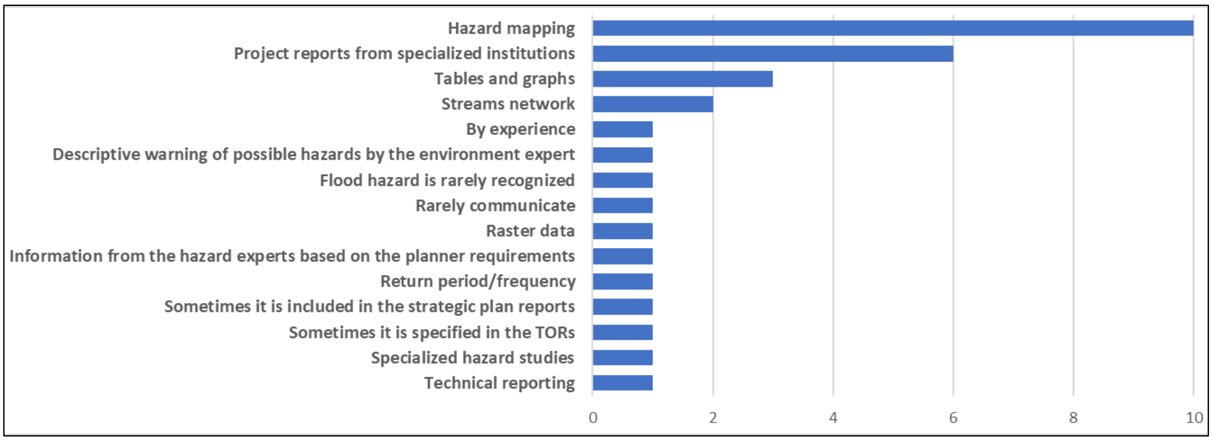


Figure 4-5: The means of hazard communication

The sufficiency of the communication methods

The methods of communicating the hazard information lean towards low sufficiency. See Table 4-5 for the related answers to hazard information communication sufficiency.

Table 4-5: The sufficiency degree of hazard information communication

1) Not Sufficient	2) Low Sufficiency	3) Moderate Sufficiency	4) High Sufficiency	Total
4	8	4	5	21

4.1.2.4. The obstacles of considering the hazard information in the spatial planning process

General obstacles

Several obstacles hinder the consideration of hazard information within the planning process, which have been mentioned by the participants. According to 10 experts, the availability of data is the major concern as data either unavailable or inaccessible, especially on the local level. 1 expert associated date scarcity with insufficient integration and cooperation between relevant authorities, which hindered data sharing. 1 expert responded that there is unclarity appointing specific authorities with the responsibility of providing the required data. In other words, usually, the responsible authorities for collecting data such as EMA, NARSS, and EEAA work in isolation from other authorities such as GOPP. Furthermore, 5 participants have flagged their concern about the accuracy of the data; for example, there is a lack of accurate and high-resolution DEMs, which is crucial for hazard modeling.

According to 9 participants, the complexity of hazard modeling prevents planners from conducting hazard assessments by themselves. On the other hand, according to 16 out of 22 participants, hazard experts are not usually involved in the spatial planning projects. Thus, in the absence of hazard experts, the hazard information either neglected or misunderstood, which causes communication problems for the hazard information.

The scarcity of historical data records raises challenges in considering rare extreme events and validating the results of hazard modeling. Moreover, insufficient fund constrains the ability to deal with the previously mentioned issues. Until recently, there was a lack of recognition from decision-makers and citizens alike for the dangers of the flood events. Figure 4-6 summarized the causes of disregarding the hazard information in the spatial planning practices in Egypt.

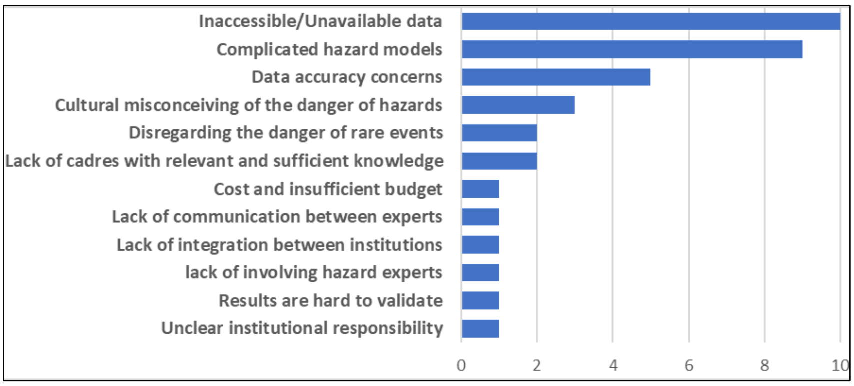


Figure 4-6: The causes of disregarding the hazard information in the spatial planning practices in Egypt

Obstacles of communication

Based on the answers of 4 experts, communicating hazard information is mainly hindered by the lack of information. Also, 3 experts stated that the data is usually incomplete and requires more effort and cost to be completed. Likewise, 1 expert commented that there is inconsistency in how the hazard information is provided.

According to 3 experts, there is a misconception of natural hazards' safety. This false sense of safety has been dominating the mindset of decision-makers and citizens for years, and consequently, increasing the burden of communicating hazard information. Furthermore, 3 experts stated that hazard information is usually neglected because of more pressing priorities from decision-makers' perspectives and financial constraints. Thus, cost and insufficient budget were highlighted by 2 experts as limitations for communicating the hazard information.

2 experts mentioned that ineffective integration between authorities is an obstacle to joining efforts and knowledge exchange. 1 expert added that there is a lack of communication and coordination between authorities. Furthermore, in terms of providing the hazard information and responding to mitigate its effects, 3 experts answered that there are unclear institutional responsibilities. This unclarity causes duplication of efforts. According to 1 expert, the laws, regulations, guidelines, and TORs do not support the integration between risk management and spatial planning. Thus, it hinders the efforts of considering hazard risk in planning.

Interrelated individual statements have expressed by experts: First, governmental and private institutions are missing the human expertise and caders, which is needed to deal with hazards. Second, the available expertise is usually excluded from the planning team or involved in later stages of the planning projects. Third, thus, owing to the technical form of the available hazard information, it could be misunderstood by planners, especially in the absence of hazard experts to explain it adequately. Fourth, this could result in an inadequate translation of hazard information into proactive actions in plans.

However, contrary to the previous points, 1 expert stated that there is no apparent reason that should hinder communication. Figure 4-7 summarizes related experts' answers to the obstacles of communicating the hazard information.

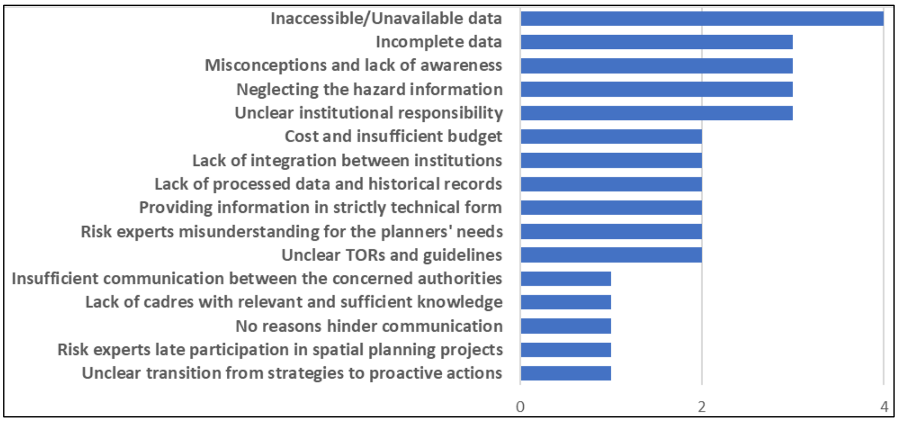


Figure 4-7: The related experts' answers to the obstacles of communicating the hazard information

Possible improvements

7 Participants have emphasized the need for capacity and awareness building for institutional personnel and decision-makers. Thus, there is a need to inform decision-makers and citizens with urban flood threats in Egypt. Furthermore, capacity building is needed for Egyptian planners to enable them to properly consider the provided hazard information. Moreover, capacity building should extend to training hazard experts that can simulate different hazard types and scenarios and can recommend possible interventions for planners.

Based on 4 experts' responses, effective integration between authorities will result in several beneficial aspects that will serve to improve the hazard assessment. Accordingly, institutional integration will boost the joining efforts and support for each other work. Furthermore, institutional integration will ease the data and knowledge exchange, thus, the required information for considering hazard into spatial planning will be available.

Accordingly, 7 experts stated that relevant institutions should strive to provide hazard information and improve data quality. Thus, data collection methods and technologies should be improved accordingly. Furthermore, according to 4 experts, the information should be provided in a proper spatial format and form. Additionally, the information should be associated with a non-technical description for planning use. There were 3 suggestions for harmonizing the process of producing, storing, and accessing the hazard information. 1 of the 3 suggestions was to establish a national database for managing and accessing hazard-related data. The other 2 suggestions were to create an online interactive platform; as 1 of the 2 stated that this would help in conducting automated analysis, which will save time, effort, and cost.

According to 1 expert, there is a need to amend national laws and regulations to support institutional integration, as well as amending the institutional guidelines and planning projects' TORs to consider the hazard information. Thus, according to 1 expert, hazard information should be considered in the earlier stages of planning to be adequately reflected in the produced plans. Likewise, 1 participant stated that hazard experts should be early involved so that they would provide planners with the required hazard information and its accurate interpretation. Alternatively, 2 experts recommended that specialized institutions could conduct risk assessment studies. Thus, interventions should be recommended directly by these studies so that planners can directly consider these recommendations. Furthermore, 1 expert added that the design criteria of vulnerable communities to hazards should be revisited based on the local context. Figure 4-8 summarizes the recommended improvement by experts to enhance the consideration of the hazard information in the planning process.

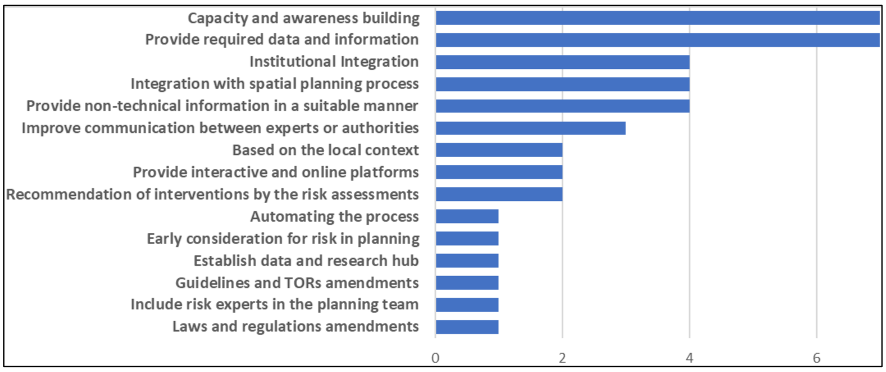


Figure 4-8: A summary of the recommended improvement by experts to enhance the consideration of the hazard information in the planning process

4.1.3. The relations between vulnerability assessment and the spatial planning process

4.1.3.1. The planners' perception of vulnerability in Egypt

According to 11 participants, vulnerability was associated with the characteristics of a specific asset. 10 participants stated that these characteristics determine the degree of the reflected impact on the asset by natural hazards. These hazards could be natural or manmade. Experts mentioned several types of assets. 9 experts mentioned the community as a critical asset, and its characteristics consist of physical, social, economic, institutional, and environmental aspects. Additionally, other types of assets were mentioned only once, including inhabited areas, environment, human activities, cities, and new developments. Furthermore, vulnerability was associated with several concepts. First, 4 experts associated vulnerability with the degree of exposure and coping capacity. Second, 3 experts stated that vulnerability is the asset's inability to face natural hazards or lack of resistance. Third, concepts such as the probability of being affected, the capability of recovery, fragility, and resilience were mentioned twice. Finally, vulnerability was related to terminologies such as sensitivity, poor conditions, lack of policies, and tools. Figure 4-9 summarizes the used concepts and terminologies to describe vulnerability.

Figure 4-9: The used concepts and terminologies to describe vulnerability

4.1.3.2. The commonly used data and methods for the vulnerability assessment in Egypt

Methods of identifying vulnerable assets

Vulnerability assessment is not a common practice in spatial planning projects in Egypt, as several participants have confirmed its rare usage. Table 4-6 illustrates the participants' answers regarding the extent of using vulnerability assessment as a planning tool.

Table 4-6: The participants' answers regarding the extent of using vulnerability assessment as a planning tool

1) Never	2) Very Rarely	3) Rarely	4) Half the Time	5) Usually	6) Always	Total
1	6	7	5	2	1	22

The experts highlighted several methods for detecting vulnerable areas. However, 3 experts stated that vulnerability assessment is an absent practice from spatial planning, according to 2 of the 3 experts, some of these methods are not mainly used for risk assessment but as part of the current status analysis. 1 expert stated that vulnerability is an indication of deteriorated communities or informal settlements. Figure 4-11 summarizes the highlighted aspects by experts regarding the vulnerability assessment methods and usage in Egypt.

According to 7 experts, the frequently used method for conducting the vulnerability assessment is the indicators' development. It is used to assess either a single dimension or multi-dimensions of vulnerability. The participants mentioned both the physical and social dimensions 7 times, whereas the economic dimension was only mentioned for 5 times. Indicators are usually selected and weighted based on literature, subjective experts' knowledge with the local context, as well as stakeholder participation and available data. Participants usually weight the indicators to represent the relative importance of each indicator. Table 4-7 presents the participants' answers regarding the extent of using weighted indicators. 12 participants stated that they usually use their own experience to assign weights. 5 experts construct weights based on stakeholders' participation. 2 experts consult other experts, whereas 4 experts use literature. 1 expert stated that the use of either subjective or objective method is based on the available data and the planning project context. Tools such as AHP, Delphi, correlation analysis, or surveys are utilized to increase the objectivity of selecting and weighting the indicators. Figure 4-10 illustrates the used method for determining indicators' weights. Moreover, the risk matrix approach was also mentioned by 3 experts, and it is usually combined with the indicator-based approach for classifying the risk degree.

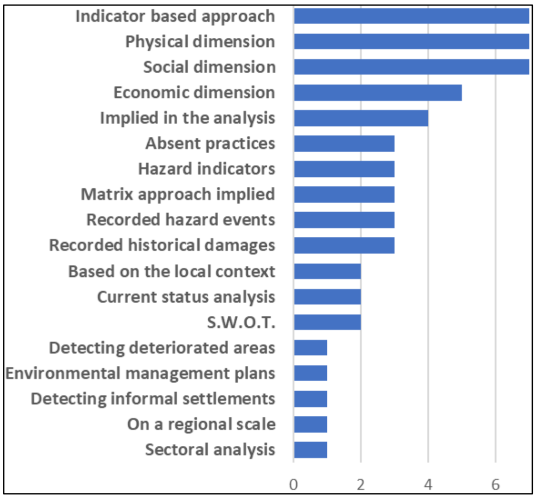


Figure 4-11: The highlighted aspects by experts regarding the vulnerability assessment methods and usage in Egypt.

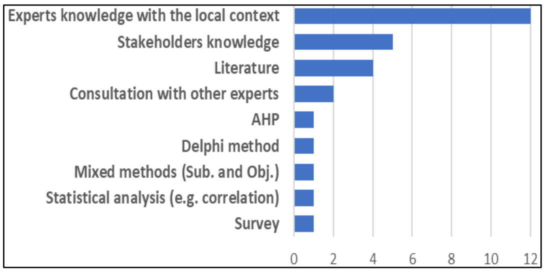


Figure 4-10: The used method for determining indicators' weights

Nevertheless, these practices are mostly substituted in the planning practices in Egypt. Thus, according to 2 experts, planners indicate vulnerable areas as part of the baseline analysis (current status analysis) as they conduct General Sectorial Analysis (GSA) to identify development's limitations, problems, and potentials. Furthermore, 2 experts added that the GSA usually substituted or complemented with sectorial S.W.O.T analysis.

Moreover, according to 3 experts, vulnerable areas could be identified when records of hazardous events are available along with records of the damaged assets and affected locations. However, this practice is described as rarely conducted. Finally, 1 expert stated that vulnerability assessment studies are often conducted on a regional scale and included either in the spatial plans issued by GOPP or in the environmental management plans issued by EEAA.

Table 4-7: The participants' answers regarding the extent of using weighted indicators

1) Never	2) Very Rarely	3) Rarely	4) Half the Time	5) Usually	6) Always	Total
2	3	2	1	11	3	22

Data

Planners mainly utilize census data from CAPMAS and physical elements' geodatabases from GOPP throughout the planning process. Also, these data sources are mostly used to develop indicators for different purposes. Table 4-8 illustrates the extent of using the census data and physical geodatabase in the planning process.

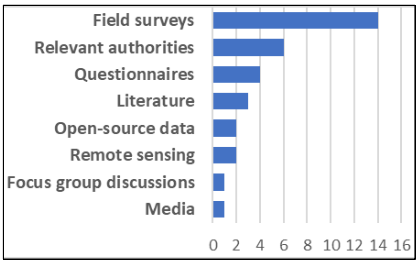


Figure 4-12: Other data sources that support the planning process

Nevertheless, the ex-ante data are usually complemented by other data sources, as illustrated in Figure 4-12. According to 14 experts, primary data from field surveys, questionnaires are usually used to update the planning inputs. Furthermore, focus group discussions were mentioned by 1 expert.

There were few recommendations of secondary data sources, which could be used when possible. First, 6 experts referred to local authorities such as governorates and municipalities, as well as national institutions such as NARSS, EEAA, ISDF and the New Urban Communities Authority (NUCA). Second, 2 experts referred to open-source data such as Open Street Maps (OSM), satellite images, and 1 expert mentioned media and news as potential sources. Finally, 3 experts mentioned literature as a knowledge base.

Table 4-8: The extent of using the census data and physical geodatabase in the planning process

	1) Never	2) Very Rarely	3) Rarely	4) Half the Time	5) Usually	6) Always	Total
1) Census data from the Central Agency for Public Mobilization and Statistics (CAPMAS)	1	0	1	2	5	12	21
2) Physical geodatabase from General Organization for Physical Planning (GOPP)	0	1	1	3	4	12	21

The sufficiency of the methods and data

According to the participants' answers, which are presented in Table 4-9, census data and physical geodatabases are sufficient for the planning usage very often.

Table 4-9: The sufficiency extent of the main sources of data

	1) Never	2) Very Rarely	3) Rarely	4) Half the Time	5) Usually	6) Always	Total
1) Census data from the Central Agency for Public Mobilization and Statistics (CAPMAS)	1	0	4	5	7	5	22
2) Physical geodatabase from General Organization for Physical Planning (GOPP)	1	0	3	5	8	5	22

However, as illustrated in Table 4-10 the majority of the participants found that the usual methods for detecting vulnerable areas are leaning towards low sufficiency.

Table 4-10: The sufficiency extent of the used vulnerability assessment methods

1) Not Sufficient	2) Low Sufficiency	3) Moderate Sufficiency	4) High Sufficiency	Total
2	10	9	1	22

4.1.3.3. **The important indicators from the participant point of view**

Questions that relate to the perception of the experts towards the important indicators in each vulnerability dimension resulted in set of indicators in each dimension. Thus, their answers were analyzed, and the indicators have been presented based on the frequency of their mentioning, then grouped per dimension. Figure 4-13 summarizes the results of the frequency analysis. The physical, social, and economic dimensions consist of 12, 16, 9 indicators, respectively.

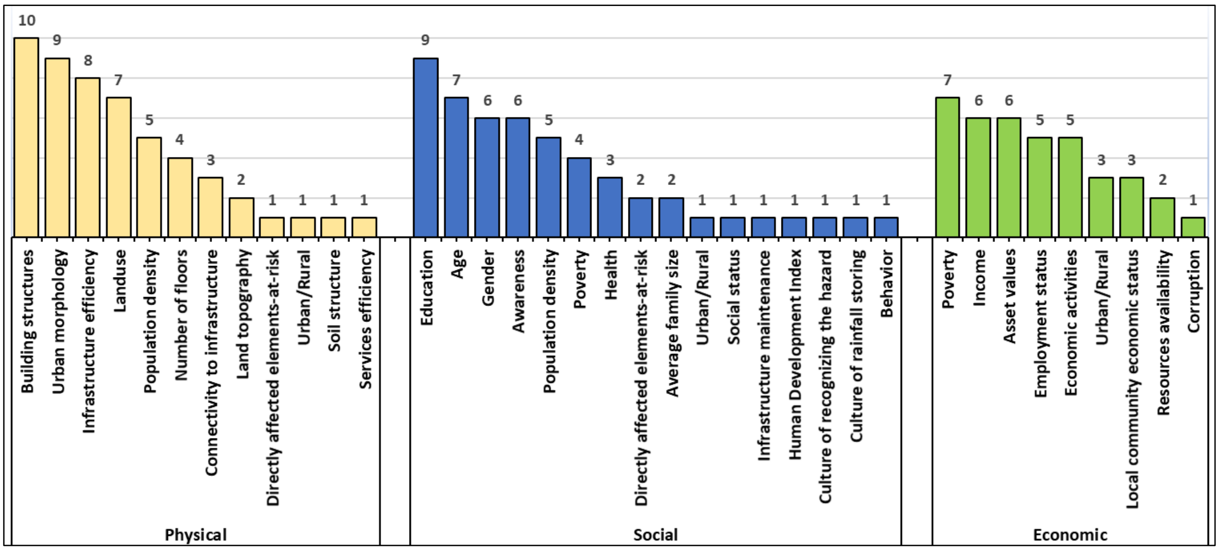


Figure 4-13: The frequency of the mentioned indicators by experts for each of the vulnerability dimensions

4.1.3.4. The communication of vulnerability assessment

According to 6 participants, vulnerability assessment is hardly communicated as it is not a common practice in the spatial planning process in Egypt. However, the available vulnerability assessment studies are usually communicated in different ways. First, based on 8 experts, vulnerability mapping is the commonly used method for communicating vulnerability. 4 experts referred to the conducted vulnerability assessment studies by specialized institutions such as EEAA, and thus, included in issued reports. 3 experts stated that vulnerability assessment could be part of the core studies of strategic plans, especially for projects which are being funded by international organizations. However, 1 of the 3 experts stated that vulnerability assessment could be annexed as a margined study with strategic plans. Based on 2 experts, the vulnerability assessment is usually associated with statistical analysis.

Also, several individual statements have been provided by experts as follows: First, the vulnerability study could be conducted by social study experts as part of the planning team. Second, planners can use their experience and knowledge with local context to identify vulnerable areas, and thus they provide qualitative description and assessment accordingly. Third, indicator development usually provides indicators' descriptions; indicators then can be used as an input for weighted overlay analysis. Fourth, the assessment is usually being conducted on the smallest possible administrative units when data is available. Finally, the assessment usually covers the multidimensions of vulnerability. Figure 4-14 illustrates the experts' description of the means of communication vulnerability.

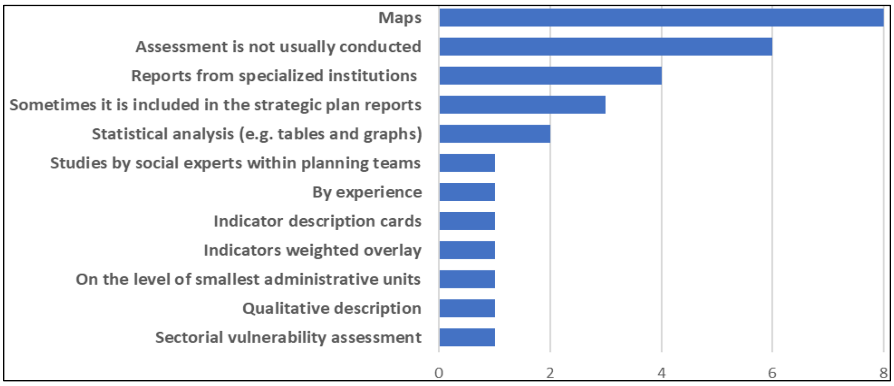


Figure 4-14: The experts' description for the means of communication vulnerability

The sufficiency of the communication methods

When participants were asked about the extent of the sufficiency of the vulnerability communication, the result showed almost a split in opinions between moderate sufficiency and low sufficiency. Table 4-11 illustrates the participants' responses to the extent of communication sufficiency.

Table 4-11: The extent of the sufficiency of the vulnerability communication

1) Not Sufficient	2) Low Sufficiency	3) Moderate Sufficiency	4) High Sufficiency	Total
3	8	9	2	22

4.1.3.5. The obstacles of considering vulnerability assessment in the spatial planning process

General obstacles

According to 10 participants, the currently followed methods are mostly inappropriate for several reasons. First, 3 experts stated that the outcome neglects the multidimensions of vulnerability. Thus, 1 expert stated that these methods do not provide a detailed assessment, while 1 expert added it fails to reflect the reality on the ground. Second, 3 statements indicated that the methods lack the appropriate mechanism to select indicators and determining weightings, accordingly, 2 experts described these methods as subjective.

The experts highlighted several issues related to data. According to 10 experts, data is usually incomplete and requires considerable processing to be used. Furthermore, 8 experts stated that data usually is inaccessible or unavailable. Consequently, the result of the assessment is challenging to be validated. 3 experts associated the scarcity of data with the lack of integration between relevant authorities and institutions. Figure 4-15 summarizes the related issues to the consideration of vulnerability assessment in spatial planning.

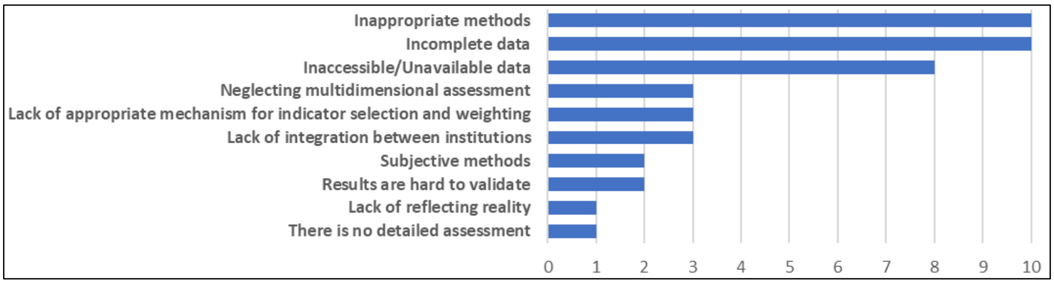


Figure 4-15: A summary of the related issues to the consideration of vulnerability assessment in spatial planning

Obstacles of communication

The experts highlighted several issues, which are hindering the vulnerability communication. These issues relate to data, methods, institutional integration, cost, awareness, and human cadres. 2 experts have emphasized issues that relate to data insufficiency and unavailability, as 1 expert added data are not usually available on a local level. Data is usually provided in poor form or unsuitable format, and thus, it requires considerable time and effort to be prepared and processed. 1 expert referred that the technical form of the information hinders the ability to understand the information and act upon it.

Furthermore, according to 1 expert, vulnerability assessments are not a common practice in Egypt, and thus, it is usually neglected. 3 experts stated that the followed methods for conducting the available assessments hold a high degree of subjectivity, thus, its accuracy could be questioned. Furthermore, based on 1 expert, these methods do not provide a full assessment that is entirely useful for planners. This was owed to neglecting a multidimensional assessment. Additionally, the transition from assessment to action was highlighted as unclear practices by only 1 expert.

According to 2 experts, there is insufficient communication between authorities, while 1 stated that there is a weak integration between them. Based on 2 experts, risk consideration is excluded from regulation and TORs, additionally, 1 expert added that vulnerability assessments are isolated from spatial planning practices. 1 expert stated that there are unclear institutional responsibilities in terms of providing data and acting accordingly. Finally, 1 expert referred to the lack of effective communication between the planning experts.

2 experts stated that cost and insufficient funds usually prevent the consideration of conducting vulnerability assessment in the planning process. The lack of awareness and misconception about risk hinder the utilization of the needed tools to analyze it. Risk assessment experts are working in isolation from spatial planners, and thus, they do not understand the spatial planning needs. According to 1 expert, competent cadres for dealing with risk are rare. Furthermore, 1 expert stated that planning teams could miss relevant expertise. Figure 4-16 summarizes the obstacles of considering vulnerability assessment in the spatial planning process.

Figure 4-16: A summary of the obstacles of considering vulnerability assessment in the spatial planning process

4.1.3.6. **Possible improvements**

General improvements

Improving data provision was emphasized by 4 experts. 1 expert stated that data should be provided for the smallest spatial unit to increase the accuracy of the assessment. Furthermore, 1 expert stated that the data consistency, accuracy, and quality should be maintained and improved for direct usage, which saves time and effort.

Other objective methods need to be explored and utilized; this is according to 5 experts. The assessment needs to span multiple dimensions of vulnerability to be effective for spatial planning; this was stated by 4 experts. 2 statements mentioned that the assessment needs to focus on the societal problems on the level of citizens or social groups rather than aggregated spatial units. As the process of the assessment consumes time, effort and it is mainly repetitive, 1 expert emphasized the need to create models that automate the process.

The internal institutional regulation and issued projects' TORs need to be adjusted considerably to require assessments that aid the spatial planning for risk reduction, this suggestion was implied by 8 experts. Furthermore, 3 experts stated that institutional integration needs to be reformed to support joint efforts and data exchange. 2 experts stated that national laws and regulations require amendments to support integration between authorities and put risk reduction as an institutional goal. Based on 3 experts, the awareness of and capacity building for natural

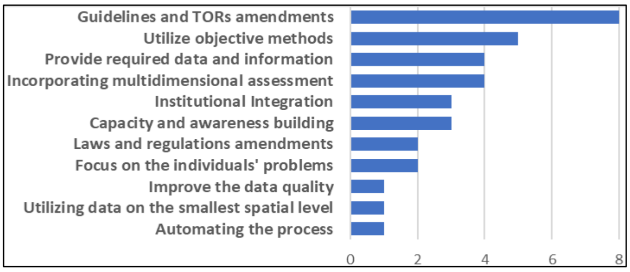


Figure 4-17: A summary of the proposed improvements to enhance the vulnerability assessment consideration in spatial planning

hazard risk reduction is required for institutions and individuals. Figure 4-17 summarizes the proposed improvements to enhance the vulnerability assessment consideration in spatial planning.

Improvements in communication

In terms of data, 5 experts stated that it should be provided in a suitable accuracy, format, and form. 4 experts added that information should be reported in a non-technical manner. 1 expert mentioned that data should be provided for the smallest spatial unit. Establishing a data and research hub will facilitate the access and consistency of the data; this is according to 2 experts.

In terms of methods, individual opinions were given. First, vulnerability assessment needs to follow objective methods to reflect more clarity and credibility. The assessment needs to be customized for the local context. Furthermore, multiple dimensions of vulnerability need to be considered. Also, it was suggested to incorporate monetary assessment as a base for quantitative assessment. The assessment process needs to incorporate stakeholder participation. Creating interactive and online platforms will facilitate access to the vulnerability information and the automation of the assessment.

An overall improvement in integrating the relevant parties is required. As experts mentioned the need for institutional integration 4 times and 2 times they referred to integrating vulnerability assessment into the spatial planning process. 1 expert stated that the communication between the planning experts and the relevant authorities need to be improved. Furthermore, 1 expert emphasized the need for amending the guidelines and the TORs. Figure 4-18 summarizes the suggested improvements for communicating the vulnerability information and assessment.

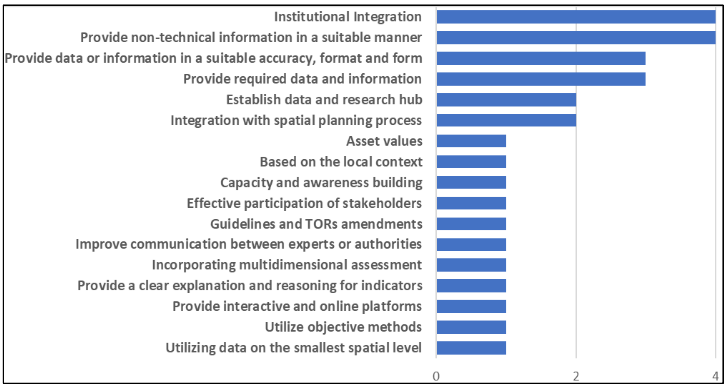


Figure 4-18: A summary of the suggested improvements for communicating the vulnerability information

4.1.4. The relations between risk assessment and the spatial planning process

4.1.4.1. The planners' perception of flood hazard risk in Egypt

11 Participants described risk as the likelihood of reflecting damage on assets. Based on 8 experts, the damage was owed to the occurrence of hazardous events. 6 participants associated risk to any event that cause negative impacts on assets, this effect could be direct or indirect according to 1 participant. Furthermore, 1 participant stated that risk is when immediate intervention is needed. 4 participants associated risk with the characterises of the endangered assets. The mentioned assets were environment, community, human activities, capital, and urban areas, of which have been mentioned by 4,3,3,2 and 2 participants, respectively. Figure 4-19 summarises the used concepts and terminologies to describe risk.

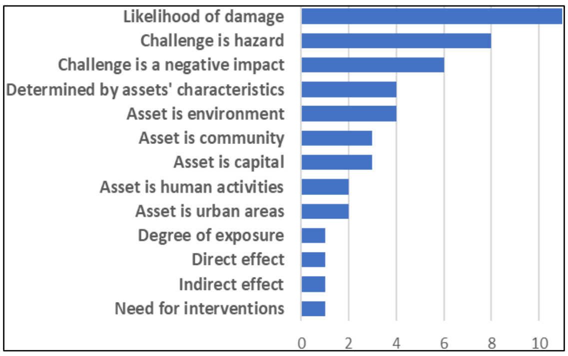


Figure 4-19: The used concepts and terminologies to describe risk

Most participants recognize risk reduction as one of the responsibilities of the spatial planning in Egypt; since 18 out of 22 participants agreed on that, accordingly, they do recognize risk as one of the planning problems and risk reduction as one of the planning goals.

However, when experts were asked about the extent of considering risk in identifying planning's goals, problems, and intervention priorities. Their answers presented in Table 4-12 revealed that the consideration of risk reduction in planning is limited. However, the question related to considering risk reduction in identifying the intervention priorities revealed an inclination to usual consideration.

Table 4-12: The extent of considering risk in identifying planning's goals, problems, and intervention priorities

Identifying	1) Never	2) Very Rarely	3) Rarely	4) Half the Time	5) Usually	6) Always	Total
Planning problem	2	5	4	2	7	2	22
Risk reduction goals	1	5	6	3	5	2	22
Intervention priorities	1	4	4	4	8	1	22

4.1.4.2. **The commonly methods for the risk assessment**

Several models define the main component of risks, which were mentioned by the participants. However, the model "Risk = Hazard * Vulnerability" was the most frequently mentioned, as it was repeated 7 times. The model "Risk=Hazard*Vulnerability*Exposure" was mentioned twice. Other models that include factors such as resilience, and sensitivity were only mentioned once. Nevertheless, according to 3 participants, the ex-ante models were usually substituted with S.W.O.T analysis to detect vulnerable locations such as slums, informal settlements, and deteriorated areas. Also, suitability analysis was mentioned as a utilized tool for avoiding the physically high-risk locations. Furthermore, 1 expert mentioned that risk study could be conducted by risk reduction consultants. Individual statements included that tools such as GIS and numerical models are also used. Nevertheless, 1 expert stated that risk assessment is not usually conducted, while 1 expert was unaware of the used methods. Figure 4-20 illustrates the mentioned risk assessment methods by the participants.

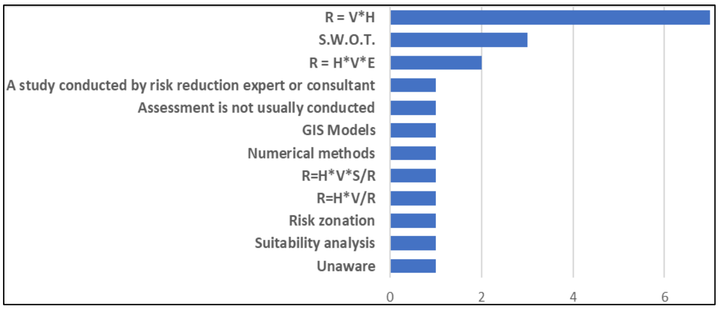


Figure 4-20: The mentioned risk assessment methods by the participants

When risk reduction is a priority in the planning practices, planners usually quantify the exposed assets to high risk to estimate potential losses. The quantified assets include the number of exposed people, buildings, and agricultural lands. Table 4-13 summarizes the participants' responses regarding the importance of pre-defined assets. Their answers revealed significant importance of exposed population, buildings, and agriculture lands. At the same time, roads and infrastructure emerged as less significant. However, exposed cars were recognized as less important. Furthermore, when participants were asked about other critical assets, 2 participants added that endangered historical locations and valuable areas should be identified. 2 participants added that exposed livelihoods' activities and land uses should be monetarily evaluated; furthermore, livelihoods included investment, commercial, and industrial areas.

Table 4-13: Summary of the participants' responses regarding the importance of pre-defined assets

	1) Never	2) Very Rarely	3) Rarely	4) Half the Time	5) Usually	6) Always	Total
1) Number of people	0	0	0	0	4	18	22
2) Number of buildings	0	0	0	0	4	18	22
3) Area of cropped lands	0	0	1	1	5	15	22
4) Length of roads	0	0	2	2	8	10	22

5) Length of infrastructure	0	0	2	2	9	9	22
6) Number of cars	0	1	2	9	4	5	21

4.1.4.3. **The communication of risk information**

According to 9 experts, risk assessment is rarely conducted as part of spatial planning in Egypt. 8 experts stated that risk assessment mostly conducted through specialized institutions such as EEAA, and thus reported. Reports will be associated with proper maps, statistical analysis, textual descriptions, and recommendations for planning actions. 5 experts referred to risk mapping as the commonly used method for risk communication. Based on 2 experts, risk assessment studies could be conducted by a specialized expert or consultant as part of the planning team or in a complementary study. The assessment usually conducted on a regional scale. However, few risk assessment studies are available. 1 expert stated that planners usually utilize published literature that include risk assessment studies and use them in the planning. Another expert said that he utilize experience and knowledge with the local context. Figure 4-21 summarizes the used methods for communicating risk in Egypt.

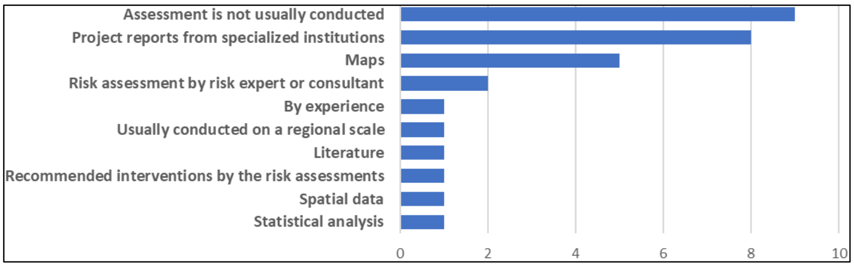


Figure 4-21: Summary of the used methods for communicating risk in Egypt

The sufficiency of the communication methods

According to planners, the used methods for communicating risk are insufficient. Table 4-14 illustrates the experts' responses to the extent of the communication methods sufficiency.

Table 4-14: The experts' responses on the extent of the communication methods sufficiency

1) Not Sufficient	2) Low Sufficiency	3) Moderate Sufficiency	4) High Sufficiency	Total
8	8	5	1	22

4.1.4.4. **The obstacles of considering risk assessment in the spatial planning process**

Risk is highly dependent on the quality of the assessment of its two main components (hazard and vulnerability). Consequently, the problems that hinder their practice or communication also reflect on considering risk assessment in spatial planning. Thus, only significant and different aspects will be highlighted to avoid repetitive descriptions.

General obstacles

Risk assessment is absent from national laws, regulations, guidelines, and TORs. According to 5 experts, risk assessments are usually conducted in isolation from the spatial planning process. 3 experts stated that financial priorities and funding challenges mostly hinder risk consideration. Thus, 1 expert added that funds are usually directed to more pressing needs over risk reduction. 3 experts perceive unclarity in translating the risk assessment results into planning actions, which was associated with the lack of well trained, and knowledgeable cadres to perform the assessment and contextualize the risk assessment results to planning action. 1 expert responded that there is a lack of proper evaluation of economic losses. The risk assessment process was also attributed to time demanding and subjectivity. Figure 4-22 summarizes the obstacles of considering risk assessment in spatial planning.

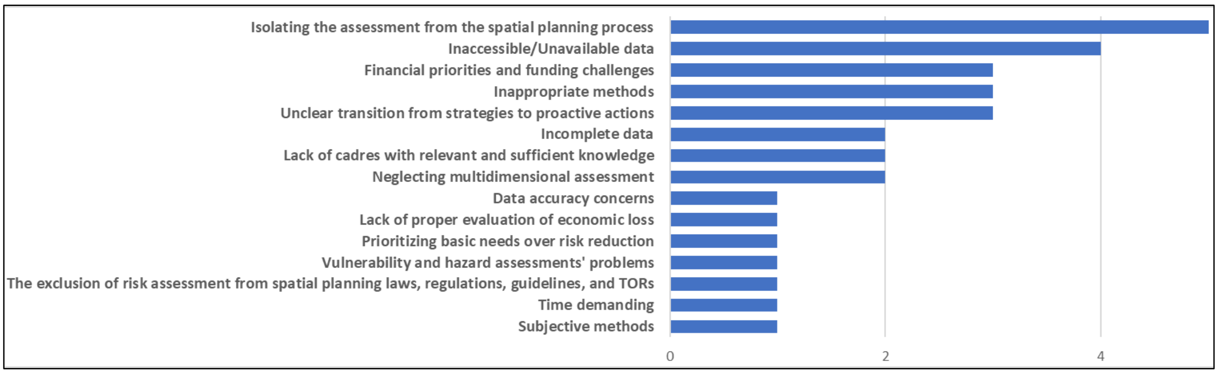


Figure 4-22: The obstacles of considering risk assessment in spatial planning

Obstacles of communication

The unavailability of risk information is the most frequently mentioned reason for the lack of communication, which was mentioned by 7 experts. 4 experts mentioned that the reason is the missing integration between the relevant authorities, and 3 out of the 4 stated that this hinders information sharing and usage. The insufficient budget limits the ability to conduct risk assessment studies within the planning projects; this was mentioned by 2 experts. Furthermore, according to 1 expert, policymakers are not aware of the benefits of conducting a risk assessment, as the role of spatial planning in the risk reduction is unrecognized by them. Furthermore, 1 expert stated that there is no transparent process to identify adequate planning measures based on the assessment. Other obstacles were mentioned, and basically, they are a direct result from the problems in the hazard and vulnerability communication. Figure 4-23 summarizes the obstacles of communicating the risk information.

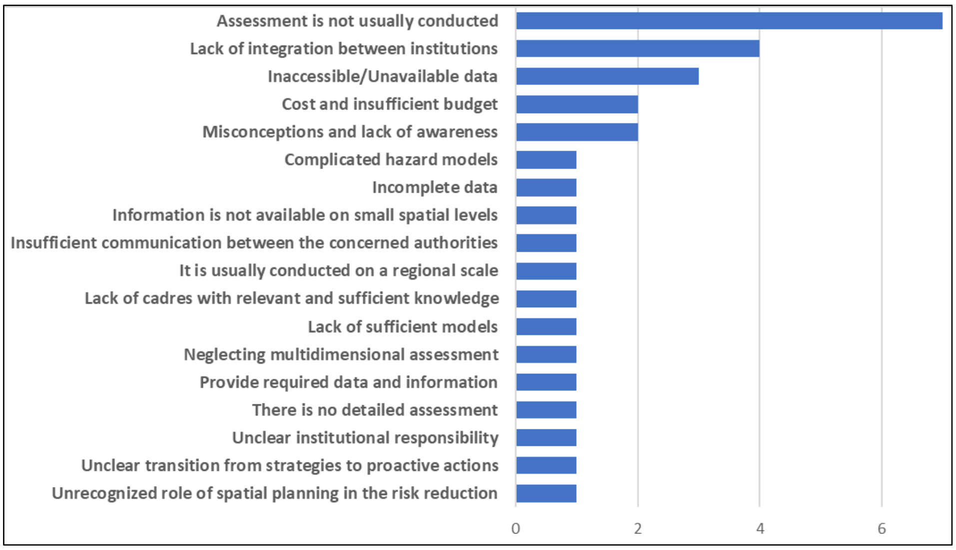


Figure 4-23: A summary of the obstacles of communicating the risk information

4.1.4.5. **Possible improvements**

The proposed improvements by experts mostly relate to improvements in the hazard and vulnerability assessments. Accordingly, only significant and different aspects will be highlighted.

General improvement

Based on 10 experts, national guidelines and TORs require amendments to embed risk assessment practices into the planning process. Also, 8 experts mentioned that relevant national laws and regulations to planning and risk reduction require amendments as well. 4 experts stated that laws, regulation, guidelines, TORs must require the risk consideration in the earlier stages of planning. Furthermore, the access to the required data for conducting the assessments need to be facilitated. Also, data must be provided on an appropriate scale for the planning needs. Capacity building is essential for providing the needed cadres to undertake the risk assessment responsibilities. The risk assessment must comprehensively consider the vulnerability's multiple dimensions to be informative for planning, and thus, recognizing the possible planning actions. Nevertheless, the implemented risk assessment approach must lean towards objective approaches to neutralize the bias in the indicators' selections and weighting. Figure 4-24 summarises the proposed improvements to enhance the risk assessment consideration in spatial planning.

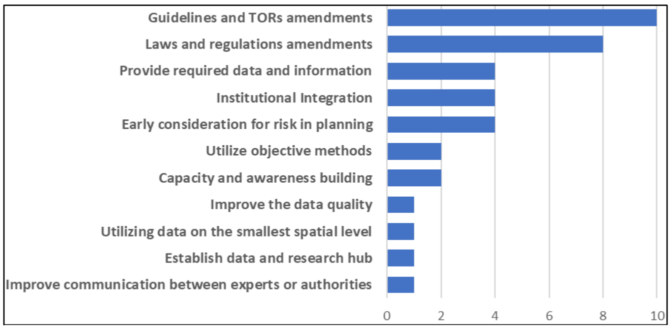


Figure 4-24: A summary of the proposed improvements to enhance the risk assessment consideration in spatial planning

Improvements in communication

The participants highly emphasized the need for capacity and awareness building for decision makers and citizens alike, this was stated by 9 experts. Furthermore, 2 experts stated that risk assessment need to be integrated in the spatial planning as part of the process. Furthermore, based on 1 expert, advisory institution such as the National Committee for Crisis/ Disaster Management and Risk Reduction (NCCDMRR) must be activated, and its recommendations must be implemented. An online national research and information hub will improve the accessibility and communication of risk information, as well as enhancing the effective integration between authorities. The risk information needs to be provided in a nontechnical manner for decision-makers and to be presented in a suitable form. Thus, the balance between the simplicity and the accuracy of the used methods should be considered. Also, the spatial variation of risk should be mapped and appropriately analysed through statistical analysis. The spatial planning academics and consultants must undertake the responsibility of informing policy- and decision-makers with the need of regulating risk assessment in the spatial planning practices in Egypt. Figure 4-25 summarizes the suggested improvements for communicating the risk information.

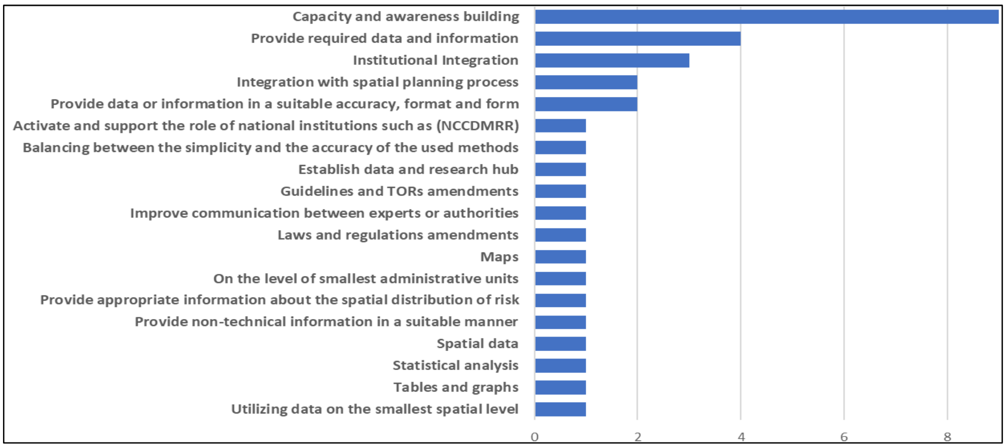


Figure 4-25: A summary of the suggested improvements for communicating the risk information

4.2. Objective 2: Analyzing the worst observed urban flood event in Alexandria, the storm of 4th November 2015

Flood depth in meters was classified into 6 classes as illustrated in Figure 4-26. The highest class (1.6-2.1m) spotted in the southeastern side off El-Montazah neighborhood. The second highest class (1.1-1.5m) was also spotted in the El-Montazah within the northwestern areas. The third and the fourth classes (0.26-0.5 and 0.6-1m) are dominating most of study area's landscape. Table 4-15 illustrates the validation points' actual water depth and the simulated depth, and Figure 4-26 additionally illustrates the validation points' location and the used pictures for validation. The Maximum flood depth was assigned for each Shyakha using the zonal statistical analysis in ArcGIS, and respectively classified into categories as presented in Figure 4-27. Only 1 unit has depth between 1.5-2.1m, and 1 unit with depth between 1-1.5m, while nearly 35% of the units are between 0.5-1m.

Table 4-15: The validation points' actual water depth and simulated depth

Point ID	Depth from Pictures in cm	Depth from Simulation in cm
1	30-50	35
2	20-50	15
3	10-20	13
4	30-50	34
4	50-65	35

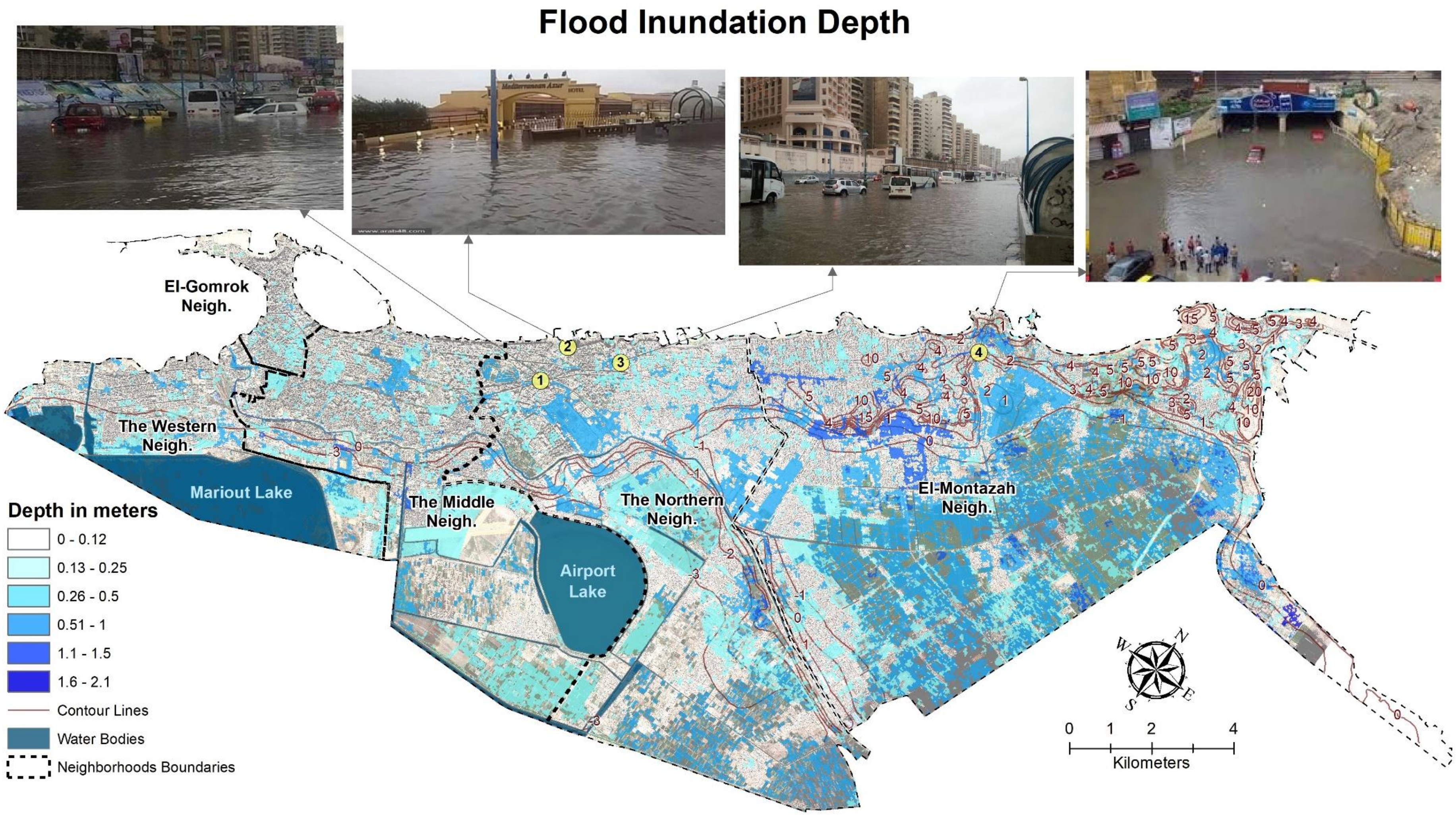
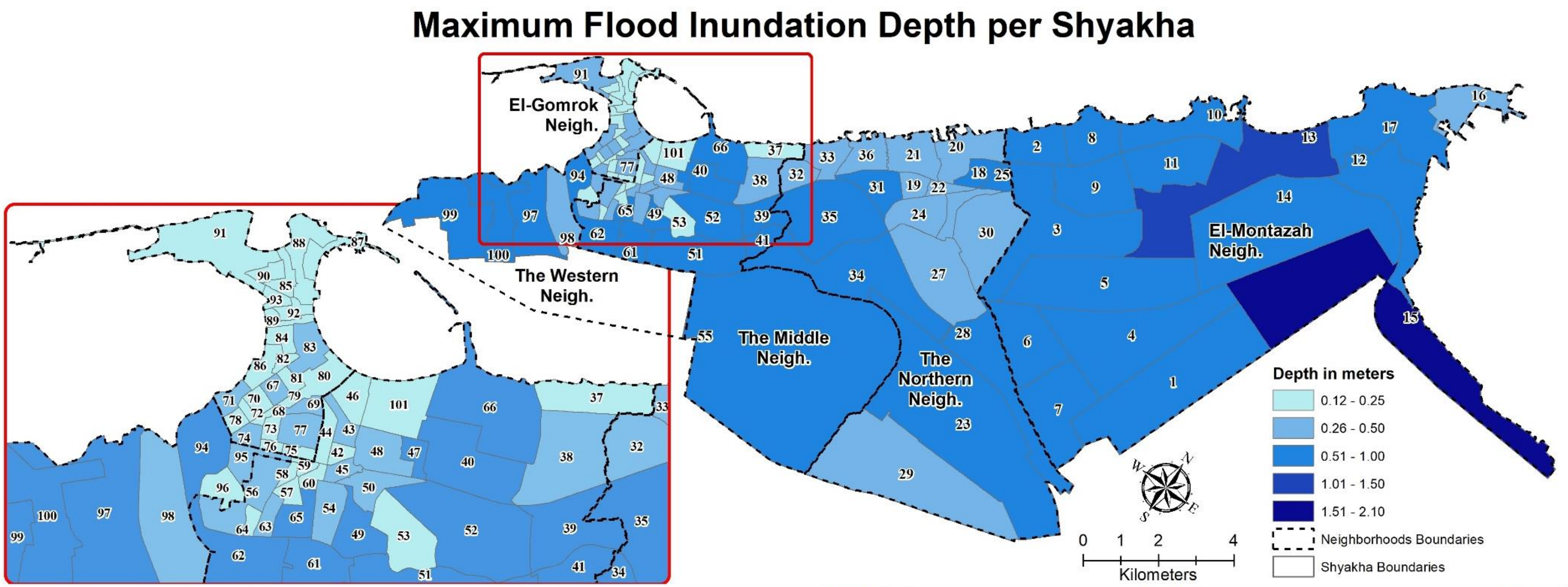


Figure 4-26: Flood's distribution, depth in meters and the location of the validation points



1	El Tawfiqeya	21	Fleming	41	Ezbat El Gamea	61	Gheat El Enab Shark	81	El Hamamil
2	El Seyouf Bahri	22	Bakoos	42	El Suri	62	Gheat El Enab Gharb	82	Souq El Barseem
3	El Seyouf Qebli and Derbala	23	Abis EL Thania	43	El Atarin Shark	63	Karmouz Shark	83	El Magharba and Souq El Tourk
4	El Kerdahi	24	El Zaheria	44	El Atarin Gharb	64	Karmouz Gharb	84	Abou Shosha
5	El Mansheya El Bahria	25	El Qasai Qebli	45	El Marghani	65	Nobar	85	El Baraka and includes - El Baraka and El Hegazy
6	El Mohagreen	26	El Mahrosa	46	El Masala Gharb and Sherif Pasha	66	El Azareta and El Shatbi	86	El Belkatria
7	Khurshid El Bahria	27	Hagar El Nawateya	47	Koom El Deka Shark	67	El Godod and El Laban	87	El Sayala Shark and includes - El Sayala 3
8	Sidi Bishr Bahri	28	Khurshid	48	Koom El Deka Gharb	68	El Genena El Saghira and Koom Bakeer	88	El Sayala Gharb and includes - El Sayala 4
9	Sidi Bishr Qebli	29	Abis EL Owla	49	El Bab El Gidid Sharki	69	El Genena El Kabira and Souq El Maeez	89	El Madoura
10	El Mandara Bahri	30	Dana	50	El Bab El Gidid Gharb and Monsha	70	El Hara El Wasah and El Takhsheba	90	El-Sayadeen
11	El Mandara Qebli	31	Abou El Nawateer	51	El Sobheya,Ezbat Sharkas and Ezbat Raafat	71	El Seka El Gidida and El Tartoshi	91	Raas El Teen
12	El Maamora	32	El Reyada	52	Ambrooz and Moharam Bek	72	El Saboura	92	El Shamoli
13	El Amrawi	33	Sidi Gaber	53	Bualino and El Eskandrani	73	El Naga El Gidid	93	Safr
14	El Nasiriya	34	Ezbat El Nozha	54	Ragheb Pasha	74	El Naga El Qidim	94	El Borsa and includes - Kafr Ashri
15	Tolmbat El Tabiah	35	Ezbat Saad	55	Abis 7-8-12	75	Bab Sidra El Jouanny and Genena	95	El Amood - Amood El Sawari
16	Abou Qir El Sharkia	36	Mostafa Kamel and Bolokly	56	El Kara,El Tobgeya and Kafr El Ghates	76	El Ayoni and El Sconia	96	Kom El Shaqafa
17	Abou Qir El Gharbia	37	El Ibrahimeya Bahri	57	Bab Sedra El Barani Shark	77	Haret El Farahda	97	El Mafroza
18	El Qasai Bahri	38	El Ibrahimeya Qebli and El Hadra Bahri	58	Bab Sedra El Barani Gharb	78	Souq El Gomaa and El Mounir	98	El Qabari Gharb and El Qabari Shark
19	Zarabanah	39	El Hadra Qebli	59	Bab Sedra Bahri includes Souq El Ghanam	79	Mashmes El Basal	99	Om kebeba - El Metras
20	San Stephano	40	Bab Sharki and Waboor El Myah	60	Gamea Sultan	80	El Mansheya El Kobra	100	El Wardian
								101	El Masala Shark

Figure 4-27: The maximum flood depth per Shyakha

4.3. Objective 3: Assessing the vulnerability of Alexandria city to urban flood hazard

This section demonstrates the results of the conducted vulnerability assessment by implementing the PCA. The section will start first by describing the general outcome from implementing the PCA, then the results of each vulnerability dimension and its latent components, followed by explaining the results of the overall vulnerability, including its associated spatial pattern. The emphasis of the results' description will be on the administrative units with high scores, which deviate significantly from the mean.

4.3.1. General PCA implementation outcomes

The data was obtained for the smallest administrative unit in Egypt named Shyakha. Consequently, the variables were constructed on the level of Shyakha units. The PCA utilized 38 out of 58 potential variables, which have been constructed for 101 Shyakha's as 20 variables were excluded owing to multicollinearity. Annex 3 includes all the constructed variables, the highlighted cells in the left column mark the used variables.

The utilized variables were grouped into three sets, as each set represents one of the vulnerability dimensions: physical vulnerability, social vulnerability, and economic vulnerability. The PCA was conducted separately for each dimension's set of variables. Consequently, three different sets of components were extracted, one set for each dimension. Table 4-16 summarizes the results of the PCA for the three vulnerability dimensions. Respectively, the resulted factor scores for each component were weighted by the ratio of the component's variance explained to the cumulative variance explained of the component's dimension. Components were mapped separately using the resulted weighted factor scores, as illustrated in Figure 4-28,Figure 4-29Figure 4-30. The summation of the weighted factor scores of each dimension's components resulted in a cumulative vulnerability score for each dimension. Additionally, the cumulative vulnerability score of each dimension was used to map its spatial distribution, as illustrated in Figure 4-31.

Finally, the cumulative vulnerability scores for the three vulnerability dimensions were added to calculate the overall vulnerability score. The maps were classified using standard deviation classes to represent the scores variations from the mean. Additionally, the standard deviation classes are used to categorize the overall vulnerability into five classes. Accordingly, class 1 represents the lowest vulnerability, and class 5 represents the highest vulnerability, as illustrated in Figure 4-32.

4.3.2. Physical vulnerability

This dimension of vulnerability was indicated by a set of three components: 1) Building's connectivity to infrastructure, 2) Buildings' structure, and 3) Residential built-up area density. These components were mapped in Figure 4-28 by using their weighted factor scores. The cumulative variance explained by the components is nearly 62% with a middling value (nearly 0.7) of Kaiser-Meyer-Olkin (KMO) according to Field (2013). Furthermore, Bartlett's test of sphericity has resulted in a significant value of ($p < 0.001$), which indicates that the utilized variables are suitable for the PCA. Table 4-16 summarises the physical vulnerability results, including the variance explained by the physical components and the loading scores of their contributing variables. The cumulative physical vulnerability was estimated by summing the weighted factor scores of these three components and was illustrated in Figure 4-31a.

4.3.2.1. **Component 1: Buildings connectivity to infrastructure**

This component explains the most in the variance of the study area by 24%, thus, it represents the main component by a slight difference from the other components. It consists of three variables, the highest contributor in this component is the variable "Number of buildings not connected to sanitation per Sq. Km", which has been recognized by its high loading score (nearly 0.84). Accordingly, the increase in the number of disconnected buildings from the public infrastructure indicates an increase in the vulnerability status. Table 4-16 shows the variance explained by this component and the loading scores of its contributing variables.

The scores' spatial distribution is represented in Figure 4-28a. The percentage of the units with high scores (scores > 1.5 Std. Dev.) is nearly 9% of the units. Shyakha units with high scores are located in the northwest of the study area in El-Gomrok and the Middle neighbourhood, as well as in the south within El-Montazah and the Northern neighbourhood.

4.3.2.2. **Component 2: Buildings structure**

The second component in the physical vulnerability dimension explains nearly 20% of the variance and it consists of three variables. The highest loading variable is the "Number of bearing walls buildings per Sq. Km" as it loaded nearly 0.76, followed by the variable "Average distance to the nearest hospital in Km" that loaded nearly 0.74, whereas the last contributing variable "Number of makeshift Buildings per Sq. Km per Sq. Km" loaded nearly 0.64. The overall component contributes positively to the vulnerability as its increase reflects an increase in the vulnerability score.

Shyakha units that have scored high in this component can be observed in the northern of El-Gomrok and the Middle neighbourhood, as illustrated in Figure 4-28b. Nearly 31% of the units scored high (scores > 0.5 Std. Dev.). Bearing walls structures are common in El-Gomrok neighbourhood as it is the oldest part of the city (Abdel-Salam, 1995).

4.3.2.3. **Component 3: Residential built-up area density**

Finally, the third component of the physical vulnerability explains nearly 18.4% of the variances in the study area. Its highly contributing variables are "Number of residential buildings per Sq. Km" and "Built-up area density", these two variables loaded 0.8 and 0.78 in the same order.

Nearly 8% of Shyakha units scored high (scores > 1.5 Std. Dev.), however, these units are mainly dispersed over the study area as shown in Figure 4-28c. Units with high scores appear near the center of El-Gomrok and the north of El-Montazah neighbourhood. However, the area of the units in El-motazah is significantly larger than the area of the units in El-Gomrok.

4.3.2.4. **The spatial distribution of the cumulative physical vulnerability**

The emerging pattern from adding the physical components' scores indicated the administrative units with high physical vulnerability, Figure 4-31a shows the spatial distribution of the physical vulnerability. Nearly 27% of the units are among the highest values (scores > 0.5 Std. Dev.). El-Gomrok and The Western neighbourhood contain the largest portion of Shyakha units with high physical vulnerability scores; however, the units in these two neighbourhoods mostly have small areas. Whereas El-Montazah and The Northern neighbourhood contain less portion of highly scored units, but they are significantly larger in area.

4.3.3. Social vulnerability

This dimension of vulnerability was identified by a set of four components: 1) Population structure, 2) Population social status, 3) Population with poor mobility, and 4) Overcrowding. These components are mapped in Figure 4-29 by using their weighted factor scores. The cumulative variance explained by the component is nearly 77.5% with a middling value (nearly 0.75) of Kaiser-Meyer-Olkin (KMO) according to Field (2013). Furthermore, Bartlett's test of sphericity has resulted in a significant value of ($p < 0.001$), which indicates that the utilized variables are suitable for the PCA. Table 4-16 summarises the social vulnerability results, including the variance explained by the social components and the loading scores of their contributing variables. The cumulative social vulnerability was estimated by summing the weighted factor scores of these four components and is illustrated in Figure 4-31b.

4.3.3.1. Component 1: Population structure

This component explains nearly 27% of the variance, and it is relatively higher than the other components. Though it consists of four variables, only two variables load the most, and thus, their contribution is significant in this component. These variables are "Number of children below 5 years old per Sq. Km" and "Population density" they loaded nearly 9.4 and 9.3 in the same order.

High scores for this component (scores > 1.5 Std. Dev.) emerge in Shyakhas' units located in the Northern and El-Montazah neighbourhoods. These units are highly populated and condensed, as well as they have large area compared to the units near the city center in El-Gomrok neighbourhood. Figure 4-29a shows the spatial distribution of this component scores.

4.3.3.2. Component 2: Population social status

The variance explained by this component is nearly 19.3%, four variables construct this component, but mainly two variables loaded highly. These two variables are "Number of widowed populations per Sq. Km" and "Number of populations who read and write but without education per Sq. Km" their loads are 0.85 and 0.8, respectively.

Nevertheless, very few Shyakha units scored highly (scores > 1.5 Std. Dev.) in this component as merely 5% of the units are among the highest scores. Highly scored units were spotted in the Middle and El-Gomrok neighbourhoods. Figure 4-29b shows the spatial distribution of this component scores.

4.3.3.3. Component 3: Population with poor mobility

This component explains nearly 18.7% of the variance in the study area, it consists of three variables, the highest loaded variables are "Number of students in primary schools per Sq. Km" and "Number of disabled populations per Sq. Km", their loads are 0.74 and 0.7 in the same order.

Nearly 30% of Shyakha units scored higher than 0.5 Std. Dev., as 7% was attributed as very high (scores > 1.5 Std. Dev.)), and 23% as High (scores between 0.5 - 1.5 Std. Dev.). The spatial distribution of these units varies between neighborhoods. The highly scored units in El-Gomrok and the Middle neighborhoods are located in their northern west. Additionally, the highly scored units were spotted in the northern units of the Northern and El-Montazah neighborhoods. Figure 4-29c illustrates the mapped scores and the variations between Shyakha units.

4.3.3.4. Component 4: Overcrowding

The explained variance by this component in nearly 12.7%, and it consists of two variables. However, the highest contributor to this component is the variable "Overcrowding rate" with a loading score of 0.91. The highly scored Shyakha units locate in the El-Gomrok and the Middle neighborhoods, as presented in Figure 4-29d.

4.3.3.5. The spatial distribution of the cumulative social vulnerability

The cumulative social vulnerability map in Figure 4-31b resulted in from summing the scores of four social components. It can be observed that 10% of the Shyakha units scored high (scores between 0.5 - 1.5 Std. Dev.). The highly scored units mostly locate in El-Gomrok, the Northern and the Middle neighborhoods. However, the units in the Northern neighbourhood are relatively larger in area than the other units.

4.3.4. Economic vulnerability

This dimension of vulnerability was identified by a set of four components: 1) population work's activities, 2) Service activities, 3) Poverty, and 4) Dependency. These components were mapped in Figure 4-30 by using their weighted factor scores. The cumulative variance explained by the component is nearly 74.3% with a meritorious value (nearly 0.81) of Kaiser-Meyer-Olkin (KMO) according to Field (2013).

Furthermore, Bartlett's test of sphericity has resulted in a significant value of ($p < 0.001$), which indicates that the utilized variables are suitable for the PCA. Table 4-16 includes a summary of economic vulnerability results. The accumulated economic vulnerability was estimated by summing the weighted factor scores of these four components and was illustrated in Figure 4-31d.

4.3.4.1. **Component 1: population work's activities**

This component explains most of the variances in the study area with 48.2%, and it consists of 10 variables. The highest three variables are related to work activities. These three variables include "Number of populations working in transportation and communication activities per Sq. Km", "Number of populations working in public services per Sq. Km", and "Number of populations working in industrial and construction activities per Sq. Km", their loads are 0.944, 0.933 and 0.932, respectively. The rest of the variables are related to the unemployed population, three of these variables loaded highly as follows: "Number of retired populations per Sq. Km", "Number of old populations who cannot work per Sq. Km", and "Number of disabled populations who cannot work per Sq. Km", their loads are 0.924, 0.914 and 0.843 in the same order.

Nearly 7% of the Shyakha units have very high scores (scores > 1.5 Std. Dev.), and 25% have high scores (scores between 0.5 - 1.5 Std. Dev.). Both categories the very high and the high scores are dispersed over the study area. Figure 4-30a shows the mapped scores for this component.

4.3.4.2. **Component 2: Service activities**

The explained variance by this component is 9.1%., and it was identified by 2 variables. The highest contributing variable is "Ratio of services land use area" as it loaded nearly 0.77. Only on Shyakha unit scored very high (scores > 2.5 Std. Dev.) in the Northern neighbourhood, whereas Shyakha units with high scores (scores between 1.5 - 2.5 Std. Dev.) are spotted in the Northern and the El-Montazah neighbourhoods, the spatial distribution of the scores is represented in Figure 4-30b.

4.3.4.3. **Component 3: Poverty**

Nearly 8.72 % of the variance explained by this component, it contains two main variables. Both two variables loaded high as "Extreme poverty ratio" loaded 0.87, and "Ratio of industrial and commercial land uses" loaded 0.71. Mainly, two shyakha units scored as very high (scores > 1.5 Std. Dev.) and they are located in E-Gomrok neighbourhood. Furthermore, nearly 24% of the units have high score (scores between 0.5 - 1.5 Std. Dev.) and they are mostly agglomerated in El-Gomrok neighbourhood, only one high unit is in the Northern neighbourhood. Figure 4-30c shows the mapped scores for this component.

4.3.4.4. **Component 4: Dependency**

This component consists of two variables and explaining 8.3 of the variances. The variable "Dependency ratio" loads significantly higher than the other variable, thus, it represents the main contributor to this component as it loaded nearly 0.8. Very high and high scores are dispersed in the study area, only 7% of Shyakha units scored very high (scores > 1.5 Std. Dev.), whereas nearly 20% scored high (scores between 0.5 - 1.5 Std. Dev.). Figure 4-30d shows the spatial distribution of this component scores.

4.3.4.5. **The spatial distribution of the cumulative economic vulnerability**

The cumulative economic vulnerability map in Figure 4-31c resulted in from summing the scores of the four economic components. It can be observed that nearly 8% of the Shyakha units scored very high (scores > 1.5 Std. Dev.), while nearly 19% scored high (scores between 0.5 - 1.5 Std. Dev.).

El-Monatazah neighborhood includes 1 very high score unit and 1 high unit in the northwestern. The Northern neighborhood contains 2 very high scores and 3 high scores, and these units mostly agglomerate in the northeastern of the neighborhood. Only 1 very high score unit exists in The Middle neighborhood, as well as 8 high scores units, of which locate in southwestern of the neighborhood. In the northern of El-Gomrok neighborhood, most of the very high and high scores were spotted, the neighborhood includes 4 very high scores units and 8 high scores units; however, these units are relatively small in size. On the other hand, the Western neighborhood includes only 1 high score unit.

4.3.5. The overall vulnerability

The overall vulnerability results from summing the cumulative vulnerability's dimensions; the summing was conducted without weighing dimensions. Respectively, the result was mapped using standard deviation classification, which resulted in 5 vulnerability classes. Class 1 represents the lowest vulnerability score, and class 5 represents the highest vulnerability score. Figure 4-32 represents the overall vulnerability scores and the variations between the Shyakha units in vulnerability.

The very highly and highly scored units are distributed across the study area. El-Gomrok neighborhood, is where most of the very high and high scores were spotted, the neighborhood includes 5 very high scores units and 12 high scores units; however, these units are relatively small in size. Only 1 very high score unit exists in The Middle neighborhood, as well as 10 high scores units, of which are located in western of the neighborhood. The northern part of The Northern neighborhood contains 2 very high scores and 3 high scores, and these units mostly agglomerate in the northeastern of the neighborhood. El-Monatazah neighborhood includes 2 high units in the northwestern. Finally, the Western neighborhood includes only 1 high score unit.

El-Gomrok contains the highest number of units with very high vulnerability scores. Additionally, the highest 3 score units is located in El-Gomrok, these units code is 90,73 and 76. The 4^{th} and the 5^{th} are the 22 and 58, and they locate in the Northern and the Middle neighborhoods, respectively.

Table 4-16: The results of the PCA for the three vulnerability dimensions

Dimensions	Components	Eigenvalue	Percent Variance Explained	Dominant Variables		Variables Loading	Sign
				Variable code name	Variable description		
Physical vulnerability	1) Buildings connectivity to infrastructure	2.781	23.867	BUNCSNT17	Number of buildings not connected to sanitation per Sq. Km	0.844	+
				BUNCNAT17	Number of buildings not connected to natural gas per Sq. Km	0.746	
				BUNCELCT17	Number of buildings not connected to Electricity per Sq. Km	0.679	
	2) Buildings structure	1.682	19.793	BLDBRGWLL	Number of bearing walls buildings per Sq. Km	0.761	+
				DSTHOSBK	Average distance to the nearest hospital in Km	-0.743	
				BUMAKSHFT17	Number of makeshift Buildings per Sq. Km per Sq. Km	0.643	
	3) Residential built-up area density	1.122	18.404	BLDRSDNO	Number of residential buildings per Sq. Km	0.801	
				BUFAR	Built up area density	0.783	
				BLDLWQUNO	Number of low-quality buildings per Sq. Km	0.47	
	Cumulative variance explained		62.064				
Kaiser-Meyer-Olkin Measure of Sampling Adequacy		0.7	Bartlett's Test of Sphericity		0	Extraction Method: Principal Component Analysis. Rotation Method: Varimax with Kaiser Normalization. Rotation converged in 4 iterations.	
Social vulnerability	1) Population structure	5.366	26.738	NCU517	Number of children below 5 years old per Sq. Km	0.94	+
				POPDEN17	Population density	0.932	
				HHWOELECT17	Number of households not connected to electricity per Sq. Km	0.764	
				OTYPRNT17	Number of households living in other rented units per Sq. Km	0.675	
	2) Population social status	2.326	19.311	WIDOD17	Number of widowed populations per Sq. Km	0.848	+
				CANRDWRT17	Number of populations who read and write but without education per Sq. Km	0.842	
				ILLTER17	Number of illiterate populations per Sq. Km	0.605	
				OldRent17	Number of households living in controlled rent units per Sq. Km	0.596	
	3) Population with poor mobility	1.374	18.732	PRMSTUDNT	Number of students in primary schools per Sq. Km	0.738	+
				DISABLED06	Number of disabled populations per Sq. Km	0.705	
				AVERFAMSIZ17	Average family size	-0.603	

	4) Overcrowding	1.01	12.733	OCROW17	Overcrowding rate	0.914	+
				NHHL2R17	Number of households living in two rooms and less per Sq. Km	0.629	
	Cumulative variance explained		77.514				
Kaiser-Meyer-Olkin Measure of Sampling Adequacy		0.75	Bartlett's Test of Sphericity		0	Extraction Method: Principal Component Analysis. Rotation Method: Varimax with Kaiser Normalization. Rotation converged in 5 iterations.	
Economic vulnerability	1) population work's activities	7.838	48.174	TRANSCOMMACT06	Number of populations working in transportation and communication activities per Sq. Km	0.944	+
				SERVOCCUACT06	Number of populations working in public services per Sq. Km	0.933	
				MANCONSTACT06	Number of populations working in industrial and construction activities per Sq. Km	0.932	
				RETRDPOP06	Number of retired populations per Sq. Km	0.924	
				OLDNOWORK06	Number of old populations who cannot work per Sq. Km	0.914	
				DISBLDNWRKR06	Number of disabled populations who cannot work per Sq. Km	0.843	
				LURSDSK	Ratio of residential land uses	0.841	
				UNEMPOL06	Number of unemployed populations per Sq. Km	0.792	
				WORWOPAYM06	Number of populations who work without wage per Sq. Km	0.71	
				OSLBRFRC17	Number of populations outside the labor force per Sq. Km	0.64	
	2) Service activities	1.606	9.089	LUSRVSK	Ratio of services land use area	0.773	+
				SERVPRIVACT06	Number of populations working for household services per Sq. Km	0.561	
	3) Poverty	1.304	8.718	EXTPOV17	Extreme poverty ratio	-0.874	+
				LUINDCOMSK	Ratio of industrial and commercial land uses	0.709	
	4) Dependency	1.135	8.292	DPNDRTIO06	Dependency ratio	0.811	+
				PRIMACT06	Number of populations working in primary activities per Sq. Km	0.413	
	Cumulative variance explained		74.274				
Kaiser-Meyer-Olkin Measure of Sampling Adequacy		0.81	Bartlett's Test of Sphericity		0	Extraction Method: Principal Component Analysis. Rotation Method: Varimax with Kaiser Normalization. Rotation converged in 8 iterations.	

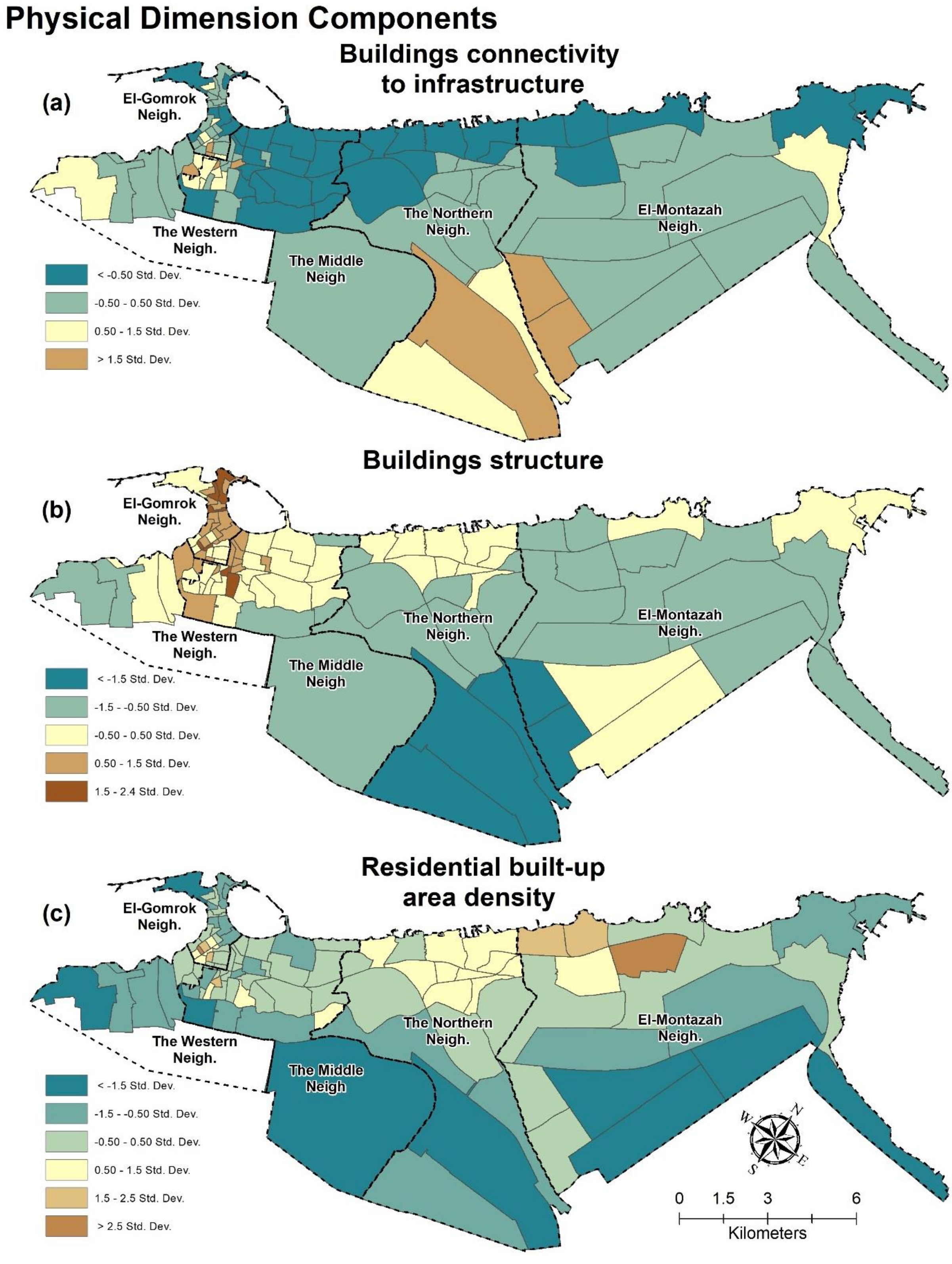


Figure 4-28: The physical dimensions components

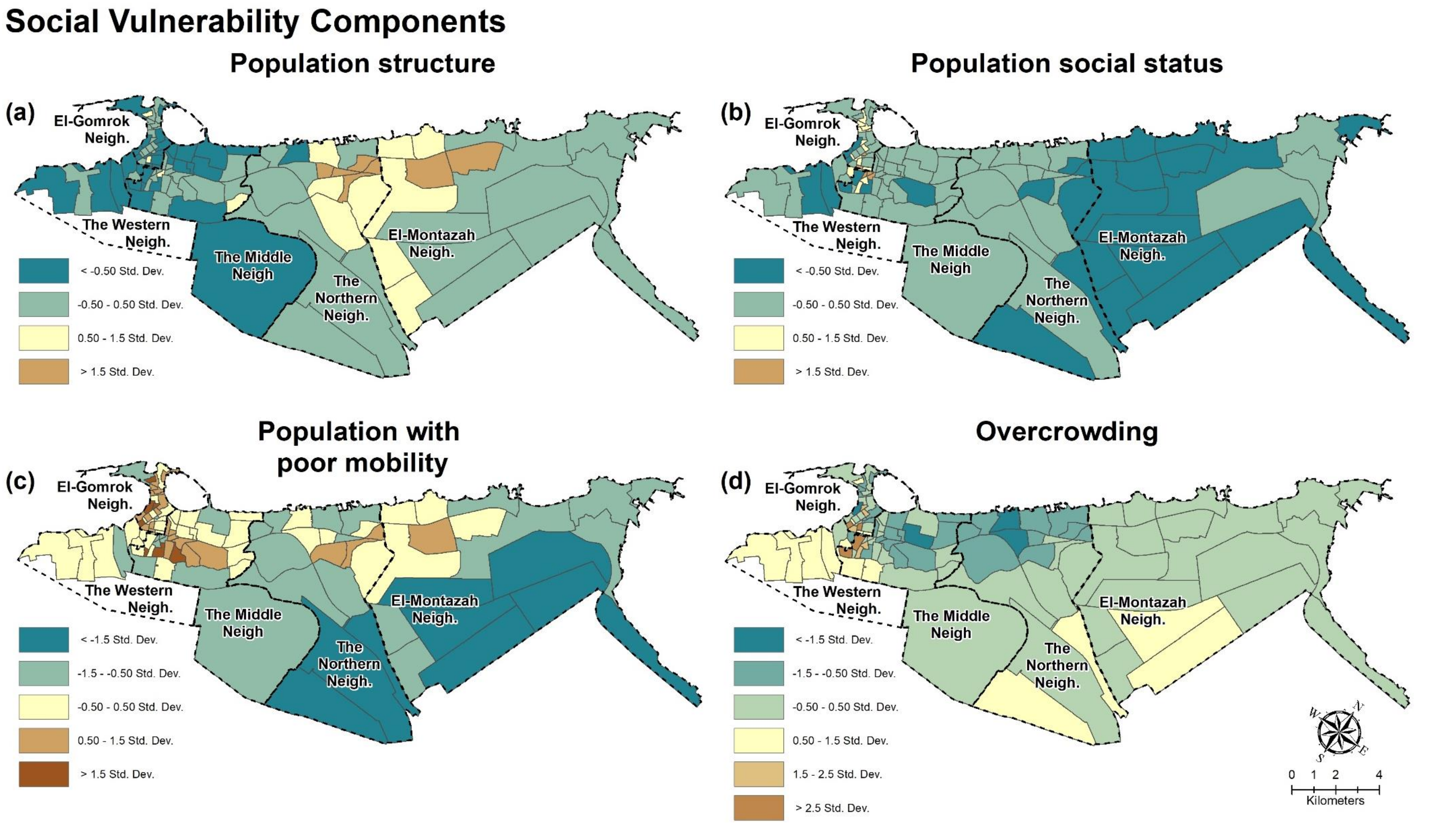


Figure 4-29: The social dimensions components

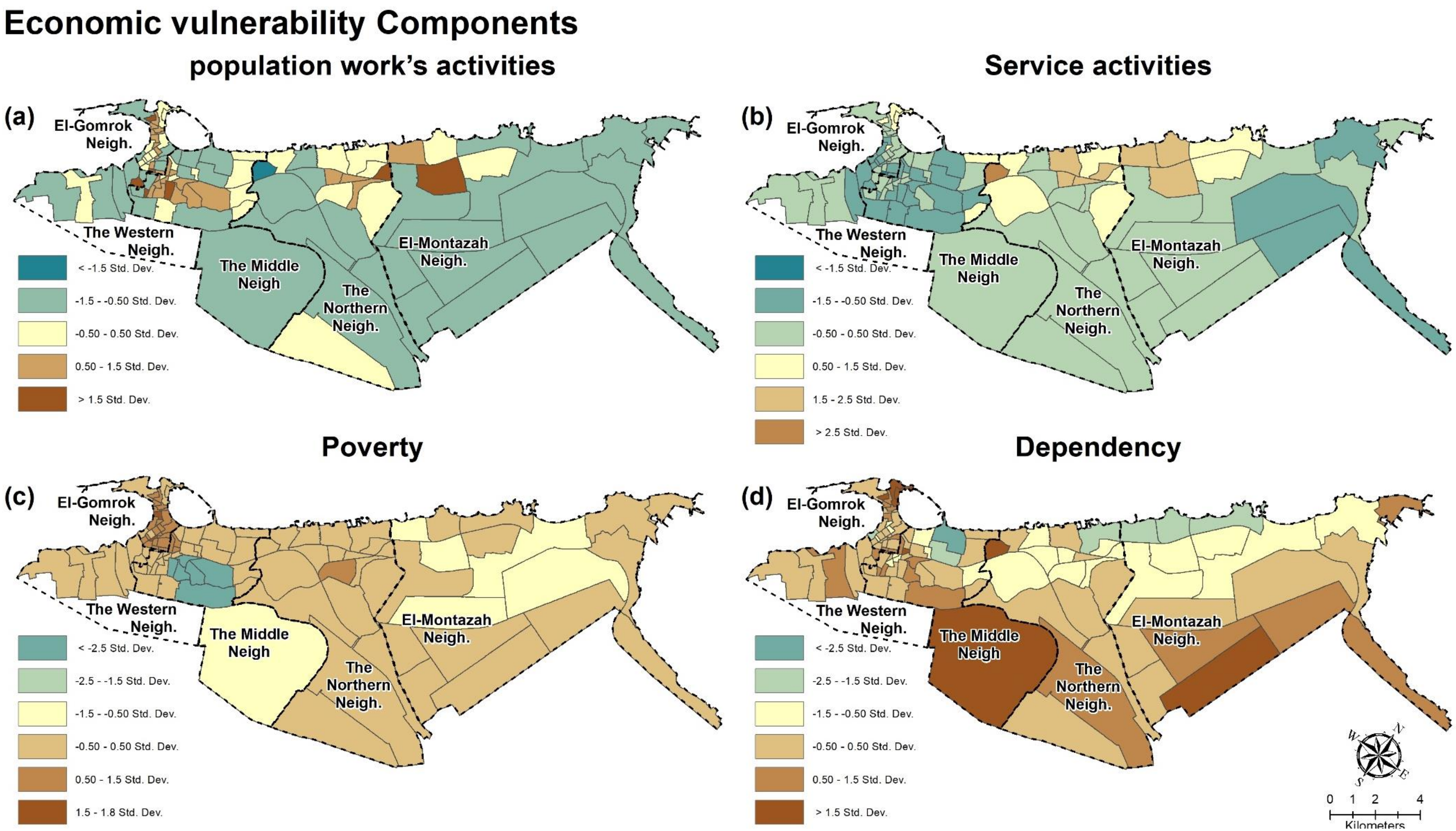


Figure 4-30: The economic dimensions components

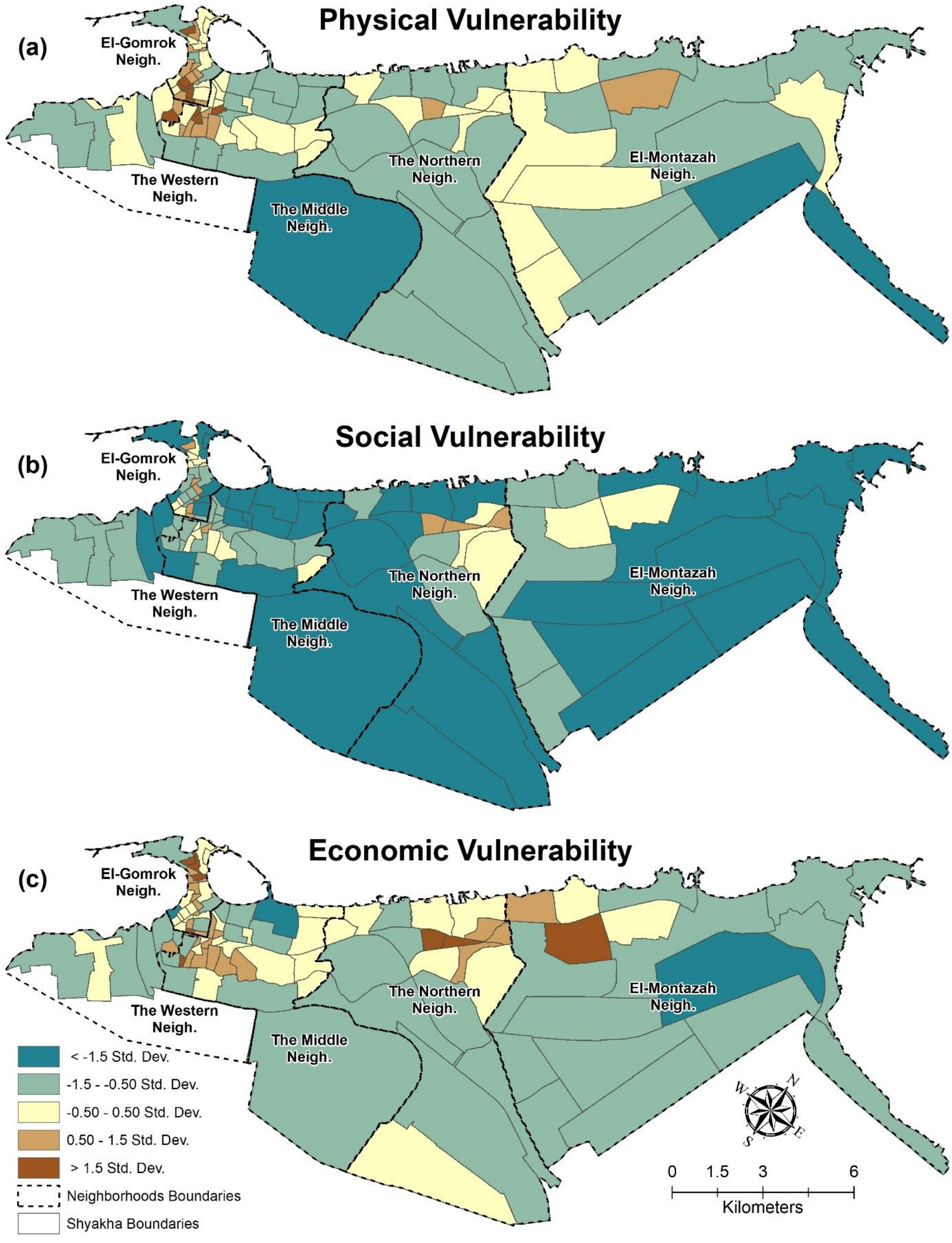
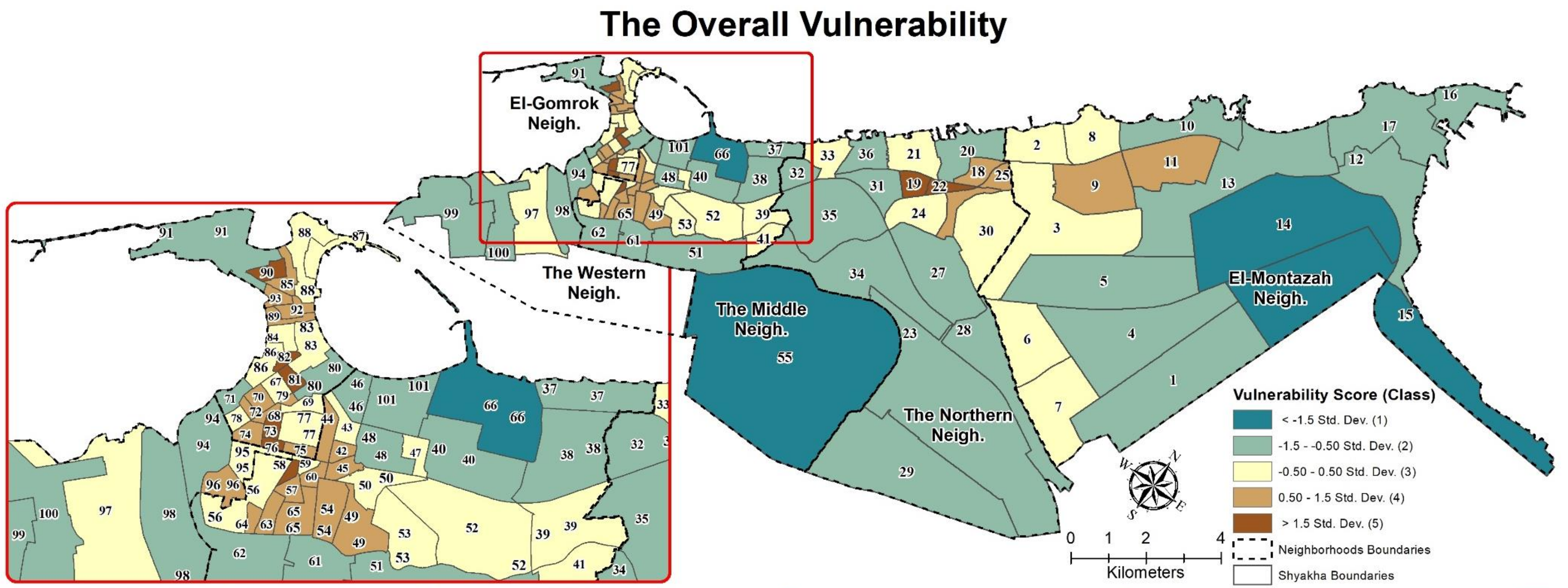


Figure 4-31: The cumulative vulnerability score of each dimension



1	El Tawfiqeya	21	Fleming	41	Ezbat El Gamea	61	Gheat El Enab Shark	81	El Hamamil
2	El Seyouf Bahri	22	Bakoos	42	El Suri	62	Gheat El Enab Gharb	82	Souq El Barseem
3	El Seyouf Qebli and Derbala	23	Abis EL Thania	43	El Atarin Shark	63	Karmouz Shark	83	El Magharba and Souq El Tourk
4	El Kerdahi	24	El Zaheria	44	El Atarin Gharb	64	Karmouz Gharb	84	Abou Shosha
5	El Mansheya El Bahria	25	El Qasai Qebli	45	El Marghani	65	Nobar	85	El Baraka and includes - El Baraka and El Hegazy
6	El Mohagreen	26	El Mahrosa	46	El Masala Gharb and Sherif Pasha	66	El Azareta and El Shatbi	86	El Belkatria
7	Khurshid El Bahria	27	Hagar El Nawateya	47	Koom El Deka Shark	67	El Godod and El Laban	87	El Sayala Shark and includes - El Sayala 3
8	Sidi Bishr Bahri	28	Khurshid	48	Koom El Deka Gharb	68	El Genena El Saghira and Koom Bakeer	88	El Sayala Gharb and includes - El Sayala 4
9	Sidi Bishr Qebli	29	Abis EL Owla	49	El Bab El Gidid Sharki	69	El Genena El Kabira and Souq El Maeez	89	El Madoura
10	El Mandara Bahri	30	Dana	50	El Bab El Gidid Gharb and Monsha	70	El Hara El Wasah and El Takhsheba	90	El-Sayadeen
11	El Mandara Qebli	31	Abou El Nawateer	51	El Sobheya,Ezbat Sharkas and Ezbat Raafat	71	El Seka El Gidida and El Tartoshi	91	Raas El Teen
12	El Maamora	32	El Reyada	52	Ambrooz and Moharam Bek	72	El Saboura	92	El Shamoli
13	El Amrawi	33	Sidi Gaber	53	Bualino and El Eskandrani	73	El Naga El Gidid	93	Safr
14	El Nasiriya	34	Ezbat El Nozha	54	Ragheb Pasha	74	El Naga El Qidim	94	El Borsa and includes - Kafr Ashri
15	Tolmbat El Tabiah	35	Ezbat Saad	55	Abis 7-8-12	75	Bab Sidra El Jouanny and Genena	95	El Amood - Amood El Sawari
16	Abou Qir El Sharkia	36	Mostafa Kamel and	56	El Kara,El Tobgeya and Kafr El Ghates	76	El Ayoni and El Sconia	96	Kom El Shaqafa
17	Abou Qir El Gharbia	37	El Ibrahimeya Bahri	57	Bab Sedra El Barani Shark	77	Haret El Farahda	97	El Mafroza
18	El Qasai Bahri	38	El Ibrahimeya Qebli	58	Bab Sedra El Barani Gharb	78	Souq El Gomaa and El Mounir	98	El Qabari Gharb and El Qabari Shark
19	Zarabanah	39	El Hadra Qebli	59	Bab Sedra Bahri includes Souq El Ghanam	79	Mashmes El Basal	99	Om kebeba - El Metras
20	San Stephano	40	Bab Sharki and Wab	60	Gamea Sultan	80	El Mansheya El Kobra	100	El Wardian
								101	El Masala Shark

Figure 4-32: The overall vulnerability's scores, classes and the variations between the Shyakha units

4.4. Objective 4: Providing an informative risk assessment for spatial planning

The maximum hazard depth in each Shyakha unit was captured suing zonal statistics analysis in ArcGIS. Since the overall vulnerability score contains negative values, it was needed to normalize these values using minimum-maximum rescaling. Consequently, the overall vulnerability values are transformed into positive values between 0 and 1. Respectively, the maximum hazard depths and the normalized vulnerability values were multiplied. The result was classified using the standard deviation classification method and was divided into 5 classes. Accordingly, class 1 represents the lowest risk degree, and class 5 represents the highest risk degree, as illustrated in Figure 4-34.

A comparison was made between the neighborhoods based on the variations of the risk values within each neighborhood, see Figure 4-33. These variations are associated with the risk values of the Shyakha units within each neighborhood. By **comparing** the changes of the **median** risk values between the neighborhoods, it was observed that there are no significant differences, especially between El-Gomrok, El-Montazah, the Middle, and the Western, while slightly lower difference emerges in the Northern neighborhood. Moreover, **comparing** the **distribution** of the values revealed differences in ranges, clearly, El-Montazah, the Middle and the Northern contain more variations and broader ranges, El-Montazah particularly unfolds significant spread in values. **Symmetrical** distribution of the risk values is noticeable in El-Gomrok, the Middle, and the Western, while El-Montazah and the Northern attributed with positive **skewness**. An **outlier** of high risk can be observed in El-Gomrok, whereas a low risk outlier can be observed in the Western. The Shyakha units corresponding to both outliers can be spotted in Figure 4-33. **Overall**, El-Montazah shows a significantly higher level of risk and variations compared to the other neighborhoods.

In addition to the statistical analysis, the mapped risk in Figure 4-34 reveals that El-Montazah neighborhood contains the only 2 units with very high risk, which are coded 9 and 10. El- Montazah also includes 2 units with high risk, which are coded 2 and 8. Within El-Montazah, the very high and high risk units are located in the northwestern side. Furthermore, 4 high risk units were spotted in the northeastern side of the Northern neighborhood. While another 3 high risk units were in the southwestern side of the Middle neighborhood.

Further analysis was conducted to illustrate how to quantify the exposure of different types of assets to different levels of risk. The quantification also compared the variations in the exposure among the neighborhoods. Annex 4 illustrates the conducted exposure analysis.

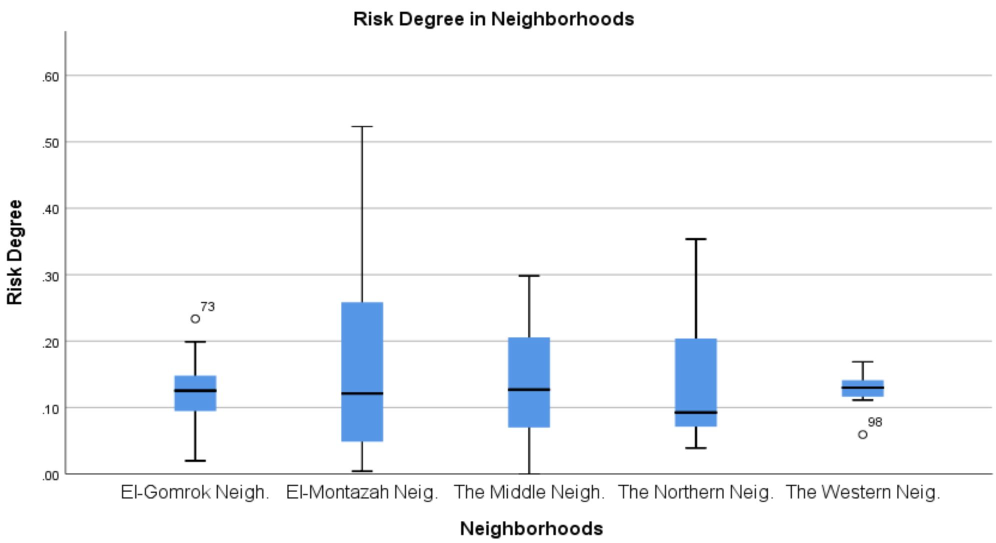
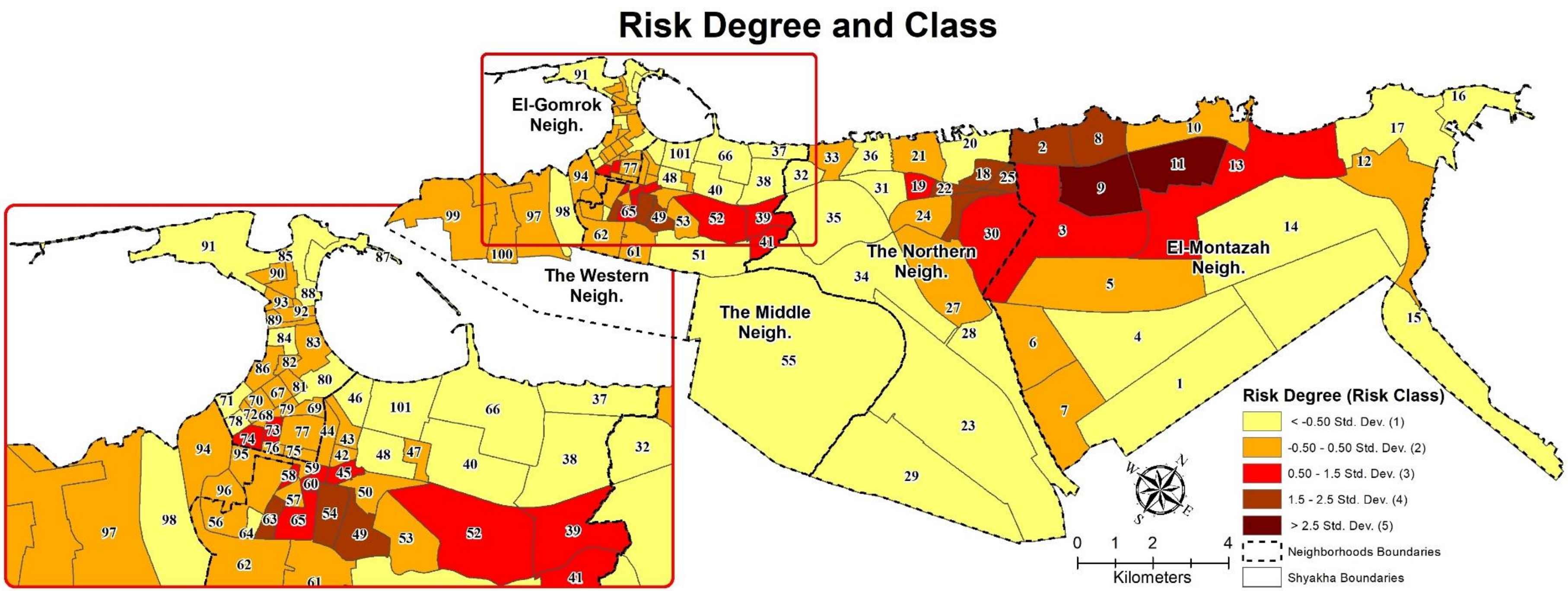


Figure 4-33: The variations of the risk values within each neighborhood



1	El Tawfiqeya	21	Fleming	41	Ezbat El Gamea	61	Gheat El Enab Shark	81	El Hamamil
2	El Seyouf Bahri	22	Bakoos	42	El Suri	62	Gheat El Enab Gharb	82	Souq El Barseem
3	El Seyouf Qebli and Derbala	23	Abis EL Thania	43	El Atarin Shark	63	Karmouz Shark	83	El Magharba and Souq El Tourk
4	El Kerdahi	24	El Zaheria	44	El Atarin Gharb	64	Karmouz Gharb	84	Abou Shosha
5	El Mansheya El Bahria	25	El Qasai Qebli	45	El Marghani	65	Nobar	85	El Baraka and includes - El Baraka and El Hegazy
6	El Mohagreen	26	El Mahrosa	46	El Masala Gharb and Sherif Pasha	66	El Azareta and El Shatbi	86	El Belkatria
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10	El Mandara Bahri	30	Dana	50	El Bab El Gidid Gharb and Monsha	70	El Hara El Wasah and El Takhsheba	90	El-Sayadeen
11	El Mandara Qebli	31	Abou El Nawateer	51	El Sobheya,Ezbat Sharkas and Ezbat Raafat	71	El Seka El Gidida and El Tartoshi	91	Raas El Teen
12	El Maamora	32	El Reyada	52	Ambrooz and Moharam Bek	72	El Saboura	92	El Shamoli
13	El Amrawi	33	Sidi Gaber	53	Bualino and El Eskandrani	73	El Naga El Gidid	93	Safr
14	El Nasiriya	34	Ezbat El Nozha	54	Ragheb Pasha	74	El Naga El Qidim	94	El Borsa and includes - Kafr Ashri
15	Tolmbat El Tabiah	35	Ezbat Saad	55	Abis 7-8-12	75	Bab Sidra El Jouanny and Genena	95	El Amood - Amood El Sawari
16	Abou Qir El Sharkia	36	Mostafa Kamel and Bolokly	56	El Kara,El Tobgeya and Kafr El Ghates	76	El Ayoni and El Sconia	96	Kom El Shaqafa
17	Abou Qir El Gharbia	37	El Ibrahimeya Bahri	57	Bab Sedra El Barani Shark	77	Haret El Farahda	97	El Mafroza
18	El Qasai Bahri	38	El Ibrahimeya Qebli and El Hadra Bahri	58	Bab Sedra El Barani Gharb	78	Souq El Gomaa and El Mounir	98	El Qabari Gharb and El Qabari Shark
19	Zarabanah	39	El Hadra Qebli	59	Bab Sedra Bahri includes Souq El Ghanam	79	Mashmes El Basal	99	Om kebeba - El Metras
20	San Stephano	40	Bab Sharki and Waboor El Myah	60	Gamea Sultan	80	El Mansheya El Kobra	100	El Wardian
								101	El Masala Shark

Figure 4-34: The risk degree's classes and variations between the Shyakha units

5. DISCUSSION

This chapter contextualizes the key findings in relation to the research objectives. Furthermore, it provides interrelated literature.

5.1. Findings

5.1.1. The current relations between natural hazards risk assessment and spatial planning practices in Egypt.

This subsection is based on the conducted questionnaire with spatial planning experts in Egypt.

5.1.1.1. The contributions of risk assessments in the current spatial planning practices in Egypt

The experts' perception

There is no consensus for the definitions of hazard exposure, vulnerability, and risk among academics and professionals. Though clear definitions for these concepts will make risk more homogeneous and easier to communicate, it is challenging to derive common definitions for these concepts from the participants' answers, and this is in line with findings by Karlberg & Nilsson (2015). However, the answers associated these concepts with distinctive elements to describe them. First, **hazard exposure** perception was strongly associated with the causes of danger and endangered elements (e.g. population, properties). This makes the hazard exposure concept clear for most of the participants. Second, **vulnerability** was moderately related to the characteristics of the endangered assets by hazard, while the most frequently mentioned asset was the community. Accordingly, it reveals that the major concerns for spatial planners are the characteristics that define the community's vulnerability to hazard. Other aspects were rarely mentioned, which reveal that their relations with vulnerability are not fully recognized. Third, **risk** is mainly attributed to the likelihood of damage or negative impacts, which is determined by the hazard's intensity and the characteristics of the endangered assets. Thus, the dominating perception of these concepts is mostly similar to the definitions provided by UNISDR (2009). Furthermore, the validity of the Wamsler (2006) findings that there is a gap of perception, terminology or knowledge between the disciplines of spatial planning and risk management is currently questionable.

There was no consensus among the participants, whether urban flood hazard is being recognized as a major hazard in Egypt or not. This could be owed to the description and triggers of urban flood that might not be clear to them. Furthermore, vulnerability assessment is not used as a planning tool since vulnerability assessment is usually conducted as part of comprehensive risk assessment studies (Karlberg & Nilsson, 2015). Though most of the experts perceive risk reduction as one of the spatial planning roles, risk reduction reflection on identifying planning's goals, problems and priorities is limited; this is in line with earlier findings of studies by Greiving & Fleischhauer (2006) and Wamsler (2014).

Data usage

Hazard information is mostly perceived as out of the spatial planning scope. Accordingly, when planners recognize the importance of considering natural hazard risk, they utilize pieces of information wherever possible. Thus, they utilize available sources or commonly accessible sources. However, these sources are mostly outdated, and the existing data have insufficient accuracy related to spatial scale.

Vulnerability information is mostly well provided through GOPP and CAPMAS' census. Nevertheless, the concern is related to the accuracy of the methods used to collect the data. Though data is mostly covering the required information, few critical information is usually missing, such as income and informal settlements. Also, due to the gap between the census issues (every 10 years), fully preparing a strategic plan (every fifteen years) and reviewing the plans (every five years), at some point, data becomes outdated. Furthermore, data on a small spatial scale could be inaccessible, which prevents the detection of spatial variations.

In 2010 the Egyptian National Strategy For Crisis/ Disaster Management And Disaster Risk Reduction (NSCDMDRR) stated the goal of developing mechanisms for exchanging data and information as well as technology among stakeholders of disaster management (IDSC, 2010). The strategy recognized data scarcity and sharing as problems that hinder risk reduction. Moreover, the strategic planning guideline in Egypt was issued in 2015, and it requires environmental analyses that include descriptions for the features of the topography, geology, soil, hydrology, climate, and pollution. The guideline states that these analyses must imply the possible associated hazards with these features (GOPP, 2015b). Additionally, the guidelines state the necessity of avoiding hazardous locations such as flood streams and valleys. However, according to the participant responses, the institutional responsibilities for providing this information are not clear and the hazard experts are rarely involved in the planning process to provide it. Alternatively, they utilize raw data with low accuracies such as high scale topographic maps or opensource DEM. Warnings have been given that hazard data is usually scarce and require to be fully harmonized to be adequately used by relevant authorities (Greiving & Fleischhauer, 2006; Wamsler, 2014).

Though vulnerability assessment is not used as a planning tool, participants have found that the data needed to conduct a vulnerability assessment is mostly sufficient for the spatial planning practices in Egypt with some reservations. Furthermore, the participants stated that they might need to validate and complement the available data with field surveys. Accordingly, the participants were concerned about the data availability on small spatial levels (blocks or building), accuracy, data and missing essential information. Utilizing updated data on small spatial scale eases the process of data validation, and result in an outcome that reflects reality, as well as it accurately reveals spatial variances in vulnerability (Wamsler, 2014; Wood et al., 2010).

Methods

Planners do not have the capacity to model hazards, and their focus is to use the hazard information directly in the planning process when it is available. Additionally, the participants prefer to acquire direct recommendations from the hazard experts or from the hazard assessment studies, which they include as recommendations in the developed plans. Since the participants associated the notion of vulnerability with the characteristics of the assets or endangered elements (e.g. individuals, community, environment, urban or rural areas etc.), vulnerable assets are recognized in planning as locations with poor conditions such as slums, informal areas, deteriorated settlements, and polluted and degraded environment. Thus, planners use traditional methods to identify these areas and their problems. These methods usually are sectoral GSA and S.W.O.T analysis (GOPP, 2015b). These methods on the other hand, are not sufficient to analyze and understand risk. However, the main purposes behind these analyses are not meant for risk reduction rather than to identify priority areas for interventions and the type of interventions. Thus, planners in Egypt use strategies such as upgrading, allocation, replacement and restoration (GOPP, 2015b; Longa, 2011). Accordingly, NSCDMDRR emphasized the need to incorporate risk assessments in the spatial planning process as a systematic mean to assess and consider risk reduction (IDSC, 2010).

Communication

The answers for questions related to the communication methods for hazard, vulnerability, and risk were mostly understood as how the information is being represented or handled. Thus, the participants' answers were mostly referring to mapping, graphs, tables, and reports. Nevertheless, several participants also recognized communication as how they obtain the information and which authority is responsible for providing it. However, the notion of communication in this research means the process of interaction between the relevant actors that result in definite receiving and understanding of the information (NOAA, 2016). Therefore, the actual/intended meaning of the notion of communication was not clear for many participants, and thus, their answers were mostly inconsistent.

The participants mentioned several authorities, which they perceive their work as related to flood risk management. Accordingly, these authorities can be divided into three sets based on their responsibilities. Figure 5-1 illustrates the institutional responsibilities in terms of data provision, planning, acting for risk management in Egypt. First, this set includes authorities, which are responsible for collecting and providing data such as NARSS, EMA, and CAPMAS, as well as GOPP and EEAA as they have their own databases. The second set consists of authorities, which conduct specialized plans, a good example for these are GOPP (e.g. strategic plans) and EEAA (e.g. environmental descriptions and environmental management plans). The third set includes authorities, which directly implement risk reduction measures such as ISDF and neighborhoods.

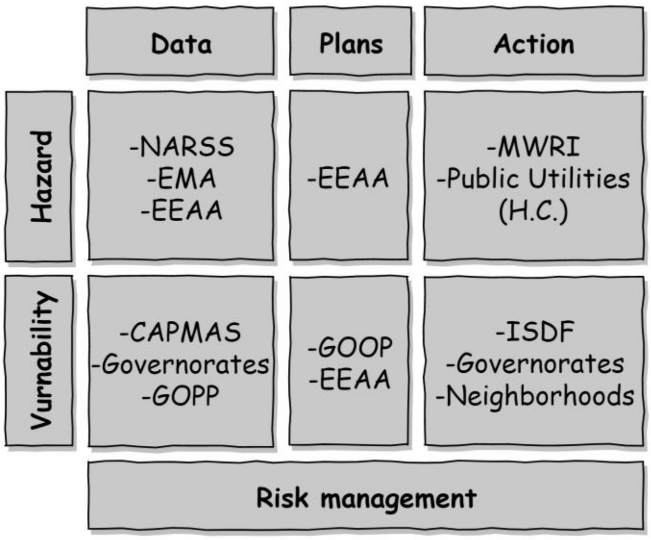

Figure 5-1: The institutional responsibilities in terms of data provision, planning, acting for risk management in Egypt

5.1.1.2. The obstacles of mainstreaming risk assessment into spatial planning and possible improvements

Obstacles of mainstreaming

Risk assessment can provide planning with the needed tool for analyzing risk to make decisions accordingly. In the Egyptian context, risk reduction is not reflected in the planning outputs, and thus, risk assessment is not used as a planning tool for risk reduction; the participant associated this with several reasons, which relate to spatial planning and risk assessment practices in Egypt. They gave several reasons, which can be grouped into 7 main interrelated aspects. These aspects include: 1) methods, 2) data 3) communication 4) institutional integration 5) funds 6) expertise and knowledge, and 7) laws and regulation. Table 5-1 compares them in terms of the frequencies of their mentioning and the diversity of reasons given for each reason. The fact that these aspects emerged from the participants' answers reveals the extent of compatibility between the Egyptian case and earlier studies (Cutter et al., 2003; Greiving & Fleischhauer, 2006; Reckien, 2018; Tate, 2012; Wamsler, 2006; Yoon, 2012).

Table 5-1: The aspects that hinder the risk reduction consideration into spatial planning, compared by their mentioning frequencies and the diversity of the given reasons

Aspects	Frequency of aspects	Diversity of reasons
Methods	66	17
Data	60	7
Communication	26	10
Institutional integration	23	3
Fund	11	3
Expertise and knowledge	10	4
Laws and regulation	5	2

These 7 groups can be ordered based on their influence and discussed as follows:

Lack of expertise and knowledge: this mainly emerges as a lack of awareness from decision-makers and citizens. Thus, risk reduction is not perceived as a priority to protect lives and sustain development. Furthermore, relevant experiences will be overlooked by the decision-making process. Also, the role of spatial planning in risk reduction will not be recognized.

Funds: Since risk reduction is not a priority, it is out of the question that funds will be allocated elsewhere. Accordingly, risk reduction will always be hampered by the lack of funds.

Laws, regulation/guidelines, and TORs: Relevant legislations and organizing frameworks do not require risk reduction from spatial planning. Thus, it will not support planning integration with relevant institutions to risk management. Furthermore, experts in risk reduction will not be part of the planning process or planning teams.

Lack of institutional Integration: The weak links between the planning authority (GOPP, governorates) and sectoral risk management authorities (e.g. EEAA, civil defense etc.) prevent the support that each authority might provide for the work of other authorities. The same findings were presented by Wamsler (2006).

Communication: This hampers the exchange of plans, knowledge, experience, and data. Thus, a conflict might occur between the sectoral plans and the spatial plans, this in line with Wamsler (2006).

Data: Scarcity, inaccessibility, accuracy, unsuitability, and inappropriate scale, all are merely a reflection of the other aspects. Other authorities do not understand the planning needs to adequately support its role in risk reduction by collecting and providing the required information.

Methods: Risk assessment, including hazard and vulnerability assessments, follows subjective approaches, which is hard to be validated. Owing to the lack of hazard information and relevant expertise, planners tend to use hazard models, which they perceive as complicated. The assessments disregard both multidimensional vulnerability and multi-hazards exposure. Though several risk assessment approaches are available to serve different needs and potentials, the need for more objective methods will require a significant improvement across the previously mentioned problems to support its success.

Possible Improvements

This part discusses the proposed improvements by the participants, mostly they addressed the obstacles, of which they highlighted and were discussed previously. Accordingly, the propositions thoroughly spanned methods, data, and communication, while limited and generic propositions were given for the other aspects. Preposition are discussed as follows;

Expertise and knowledge: The participants required capacity and awareness building as a necessary step for risk consideration in spatial planning. Awareness is crucial to promote spatial planning role in risk reduction for decision-makers and citizens, and thus, they strive to support this role by amending legislations and providing funds. Incorporating risk assessment in the planning practices will require the inclusion of new expertise and knowledge in the planning process (Wamsler, 2014; Wamsler & Pauleit, 2016).

Funds: Though there were no specific suggestions to deal with funds, promoting risk reduction importance within the spatial planning for the decision-makers will change their mindset to allocate more funds for this purpose (Wamsler, 2014; Wamsler & Pauleit, 2016).

Laws, regulation/guidelines, and TORs: This will legally oblige the relevant authorities to enforce risk reduction.

Institutional integration: The importance of identifying the different risk reduction actors were emphasized by Wamsler (2014). This is necessary to achieve a better flow of information and expertise, as well as joining and harmonizing the efforts of risk reduction.

Communication: Non-technical information is preferred for communication, especially for the hazard information, and it was recommended to be the base for communication to reduce the gap of knowledge between the risk experts and the planning experts (Wamsler, 2006). Participants proposed to disseminate the results in an online interactive platform to increase the transferability of the information to different actors.

Data: Provision of the needed data to conduct the risk assessment within the planning process is necessary; this includes both hazard and vulnerability information. Furthermore, the participants emphasized: 1) improving the quality and the structure of the data so that it requires less time for preparation and processing. 2) improving the accessibility for the data by establishing an online research and data hub or 3) improving the integration between the relevant authorities. Thus, planners will focus mainly on the process; this aligns with the findings of earlier studies (Snoeren et al., 2007; Sterlacchini et al., 2018; Williamson, 2004). In this context, the availability of open Spatial Data Infrastructure (SDI) has several advantages. For example, SDI will increase the harmony and the accessibility to the data that is needed for the risk assessment. Additionally, it will facilitate the flow of information between the relevant authorities and increase the capacity of communication (Sterlacchini et al., 2018; Williamson, 2004).

Methods: In the same line with Karlberg & Nilsson (2015), participants have agreed that the implementation of objective methods is indispensable to ensure transparency. Moreover, early incorporation of risk assessment in the planning process was emphasized by the participants, the exact outcome was recommended by Greiving & Fleischhauer (2006). Multiple risk consideration is widely highlighted by literature (Fleischhauer, 2008; UN, 2015; Wamsler, 2014), which was also flagged by the participants. Participants also recommended the utilization of data on the smallest spatial level as possible for better representation of the spatial variations. This has been illustrated by different studies working on investigating vulnerability variations on the local level (de Sherbinin & Bardy, 2015; Wood et al., 2010; Yoon, 2012). Regulating the process will improve its harmonization for comparability and possible automation. Nevertheless, it might hinder creative thought to deal with exceptional cases (Karlberg & Nilsson, 2015).

5.1.2. Analyzing the worst observed urban flood event in Alexandria

5.1.2.1. Urban flood hazard information analysis

The acquired flood simulation for this event revealed high levels of depth reaching 2 meters in some locations. The flood depth was usually high near tunnels. It was expected owing to the city terrains that most of the flooded areas will be in lowland in the south of the city. However, the simulation revealed that water was mostly trapped in the voids of the built-up area; this can be because of the artificial obstacles within the cites such as buildings, sidewalks, roads, walls. Furthermore, flood was spatially distributed over the agricultural lands in the southern areas owing to its flat and low terrains. This caused considerable exposure for the agricultural land in these areas. The results aligned to earlier studies, which reported that the flood event on the 4th of November 2015 caused critical flood depth (Bhattacharya et al., 2018; El-Boshy et al., 2019; Zevenbergen et al., 2017).

5.1.3. The assessment of the vulnerability of Alexandria city to urban flood hazard

5.1.3.1. The suitable indicators for assessing the multidimensional (social, economic, physical) aspects of vulnerability in the context of urban flood in Alexandria

Suitable indicators considered relevant to urban flood were based on literature and experts' knowledge with the local context. Nonetheless, PCA was used to eliminate the irrelevant variables based on a statistical role of thumb (e.g. high correlation, low communality, KMO etc.). Accordingly, 38 out of 58 indicators were used. Similarly, this was applied by Cutter et al. (2003) and Török (2018). Therefore, PCA is usually used by researchers to evade the need for subjectively developing indicators for vulnerability assessment; furthermore, PCA provides an objective statistical method to construct, weight, and analyze indicators (Reckien, 2018; Yoon, 2012). On the contrary, the studies in the Egyptian context (El-Barmelgy, 2014; El-Boshy et al., 2019; Mohammed, 2017) are mostly subjective and focus on the physical dimension and do not provide the rationale for their selection and weighing of indicators.

5.1.3.2. Institutional databases (e.g. census data and physical geodatabases, etc.) utilization to assess the different dimensions of the vulnerability by PCA

The participants perceived the institutional databases as sufficient to acquire the multiple dimensions of vulnerability information. Furthermore, this research found that the utilized data (institutional databases) is sufficient to conduct the multidimensional vulnerability assessment by PCA. This also aligns with the previous studies that identified institutional databases (e.g. census and physical geodatabase) as rich sources and usually utilized by planners to acquire the vulnerability information (Cutter et al., 2003; Greiving & Fleischhauer, 2006; Yoon, 2012).

The vulnerability components, which resulted from PCA were mapped separately to achieve better communication. This provides clearer insight to the contribution of each component to vulnerability, as well as the highly contributing indicators in each component. Accordingly, this will enhance the communication of vulnerability information. PCA attributed to difficult communication owing to the complexity of the statistical methods, thus, mapping individual components was in line with suggestions given by previous literature to improve communication (Reckien, 2018; Yoon, 2012).

5.1.4. Providing an informative risk assessment for spatial planning in Egypt

5.1.4.1. Risk information analysis for the use of spatial planning

The statistical analysis reveals the high variations of risk values between Shaykha units. El-Montazah neighborhood contains the highest variation of risk as well as units with the highest risk values. The very high risk in Alexandria is not a combination of extreme cases of vulnerability and hazard intensity, however, it is a combination of middle values of hazard and vulnerability. Conducting the risk assessment on the level on Shyakha units is suitable to show most of the spatial variations. This is in line with the studies by de Sherbinin & Bardy (2015) and Wood et al. (2010), which argue that the risk variations will stand out from utilizing data on smaller spatial levels such as city's blocks or buildings. Spatial variations are important to be spotted as this narrow down the scope of the needed intervention to precise locations.

5.2. Mainstreaming risk reduction into spatial planning practices in Egypt

However, the main concern is how to initiate the mainstreaming not to be limited but to consider the feedback from the spatial planning experts in regard to the existing obstacles and possible improvements of mainstreaming. Wamsler (2014; 2016) work has introduced different strategies of integrating new goals into an existing and functioning process. Thus, it is needed to recognize which options are available for mainstreaming. Incorporate risk reduction into spatial planning requires: first, to distinguish the institution or actors which are responsible for risk reduction in terms of data collection, planning, and implementing actions (see Figure 5-1). Second, suitable mainstreaming strategies should be identified accordingly.

Strategy 7 "Directed mainstreaming: educational mainstreaming" mainly supports the rest of the other strategies. This strategy is suitable to handle the lack of expertise and knowledge as it promotes for awareness and capacity building. Furthermore, it aims at providing the needed funds for supporting the needed activities for risk consideration (Wamsler, 2014; Wamsler & Pauleit, 2016). This strategy is indispensable to initiate risk reduction consideration in spatial planning practices in Egypt.

Laws, regulations, guidelines, and TORs, need to be amended to consider the implementation of **strategies 1 and/or 3**. Strategy 1 "Add-on mainstreaming" requires the creation of an entirely new entity that is separate from or under GOPP; the new entity will be directly responsible for achieving risk reduction. In the case that a new entity was created under GOPP this requires the implementation of strategy 3 "Managerial mainstreaming". Thus, internal changes in GOPP's institutional framework must be conducted in terms of management, job descriptions of the personal assets, as well as the formal and informal working norms and institutional regulation, thus, the new goal will be institutionalized (Wamsler, 2014; Wamsler & Pauleit, 2016).

Problems related to institutional integration, communication and data can be addressed by the activities of **strategies 5 and 6. Strategy 6** "Inter-organizational mainstreaming: external mainstreaming" promotes for horizontal integration between different organizations, institutions, and stakeholders to support each other work in terms of exchanging data, information, and studies, as well as joining effort with respect to avoiding efforts duplication (Wamsler, 2014; Wamsler & Pauleit, 2016). Whereas **strategy 5** "Intra-organizational mainstreaming: internal mainstreaming" is providing further support by vertically coordinating between the departments and the sectors of the organization, which operate on different scales, levels, and specialties. Also, it includes cooperation with other related entities (Wamsler, 2014; Wamsler & Pauleit, 2016).

Adopting risk reduction as a new institutional goal will require changes in the followed methods, and thus the implementation of **strategies 2 and 4** is indispensable. **Strategy 2** "Programmatic mainstreaming" requires from the organization (GOPP) to change its core work to include the new goal among its other goals, which will reflect on the organization's final product in terms of plans. Additionally, **Strategy 4** "Regulatory mainstreaming" require changes in the adopted frameworks' methods, tools and procedures, which are related to the type of work that the organization produces so that the new goal will become part of the practices of which organized by laws, regulation, guidelines, and TORs (Wamsler, 2014; Wamsler & Pauleit, 2016).

5.3. The potentials and the limitations of the used data and methods

5.3.1. Objective 1:

The questionnaire was conducted using the online platform survey monkey, while the content analysis conducted using ATLAS.ti 8

5.3.1.1. Potentials

- Survey monkey was powerful and flexible in structuring the questions as were perceived by the researcher, and it allowed the dissemination throughout several means such as emails and social media.
- The collected information throughout the questionnaire was sufficient to cover the related research question.
- The use of ATLAS.ti 8 allowed to construct themes, categories and assign codes in easy manner. Furthermore, the software provides several analysis tools to quantitatively analysis the codes and explore the data patterns. For example, in the research context, codes frequency per category (question) was used to analyze to participants' answers and compare them.

5.3.1.2. Limitations

- Paid subscription in Survey monkey is required for constructing questions above certain limits, but most importantly, to be able to download the results.
- ATLAS.ti 8 codes condense the meaning, thus some information might be lost in the analysis. The coding process requires considerable time and effort. Dividing the answers based on potential subgroups of participants was found challenging using the software. However, the participants in the context of this research are homogeneous.

5.3.2. Objective 2:

The urban flood information was provided by DPRI in Kyoto University, Japan. The simulation was conducted by RRI model by utilizing open-source data.

5.3.2.1. Potentials

- The model in its GUI release can directly retrieve online data and use it directly to generate the flood simulation. Furthermore, online data can be substituted with customized inputs for better accuracy (Sayama, 2017).

5.3.2.2. Limitations

- Accurate and high-resolution inputs (DEM, rainfall, landcover, etc.) are required to improve the simulation (Bhagabati & Kawasaki, 2017; Nastiti et al., 2015).
- The GUI release does not allow validation. However, validation is possible by a source code release (CUI), which is challenging to use (Sayama, 2017).
- Validation data is scarce, only a few pictures from the media were available for validation, and they only covered the northern part of the city, while no pictures were available for the southern areas.

5.3.3. Objective 3:

PCA was utilized to conduct a systematic and semi-quantitative vulnerability assessment by employing institutional databases.

5.3.3.1. **Potentials**

- Following an inductive approach for vulnerability assessment allows objectivity and transparency (Karlberg & Nilsson, 2015; Yoon, 2012).
- PCA facilitates the understanding of the characteristics of individuals and communities using a large set of data and eliminating redundant variables (Reckien, 2018; Yoon, 2012).
- PCA provides an objective and systematic approach that justifies indicator usage and weighting (Reckien, 2018; Török, 2018; Yoon, 2012).

5.3.3.2. **Limitations**

- The following of a complicated statistical process holds challenges in communicating the information for relevant actors (Reckien, 2018; Yoon, 2012).
- The usage of more variables does mean an increase in the explained variances (Reckien, 2018).
- More data is required to validate the vulnerability results by conducting a simple regression between actual damages and the vulnerability scores (Yoon, 2012).

5.3.4. Objective 4:

Risk was the outcome of multiplying the maximum flood depth by the normalized vulnerability score.

5.3.4.1. **Potentials**

- Risk mapping visualizes the information for the relevant actors, which allows for better communication, and comparability between units (de Sherbinin & Bardy, 2015; Török, 2018; Wood et al., 2010).
- Furthermore, the statistical analysis gives a more in-depth insight into the differences between neighborhoods and the variations of risk between units (de Sherbinin & Bardy, 2015; Wood et al., 2010).
- It allows identifying locations with the priority of intervention, based on the performance of the units across the components possible interventions can be identified (de Sherbinin & Bardy, 2015; Török, 2018; Wood et al., 2010).

5.3.4.2. **Limitations**

- The choice of using of the maximum flood depth instead of minimum or average shows uncertainty associated with the risk levels (Papathoma-Köhle et al., 2017; van Westen & Greiving, 2017).
- The risk degree is an absolute value that needs to be validated by real damages occurrences (van Westen & Greiving, 2017; Yoon, 2012).

6. CONCLUSION AND RECOMMENDATIONS

6.1. Conclusion

The main aim of this research is to demonstrate how risk assessment can be mainstreamed in the mechanism of the spatial planning framework in Egypt to improve risk reduction. Alexandria was taken as a case study since it was hit by a major flood event in 2015, which caused considerable human and economic losses. The main findings of this research were concluded in the context of the following research objectives.

6.1.1. Objective 1: The current relations between natural hazards risk assessment and spatial planning practices in Egypt.

The analysis of the questionnaire's results revealed that currently, there is a weak consideration of risk reduction in the spatial planning practices in Egypt. Thus, risk assessment is not currently used as a planning tool. However, the majority of the participants' perception towards relevant concepts to risk management (hazard exposure, vulnerability, risk,) were clear and similar. Thus, they perceive risk reduction as one of the planning goals. On the other hand, the patients' notions of communication were inconsistent. Hazard information was found to be scarce by the participants, however, the available data for planning purposes (e.g. CAPMAS: census, GOPP: physical geodatabase) was found to be sufficient to obtain the vulnerability information. Whereas the methods the utilized analysis methods (GSA, S.W.O.T) in planning were found to be insufficient and subjective to analyze and understand risk, and thus, that is why risk assessment is essential to be utilized in planning.

Further results from the questionnaire included the participants' opinions about the obstacles of risk assessment integration into spatial planning, as well as the needed improvements to achieve this integration. Owing to the considerable number of opinions and to achieve better understanding, obstacles and improvements were grouped into 7 main aspects. These aspects were ordered according to the frequency of their mentioning included 1) methods, 2) data, 3) communication, 4) institutional integration, 5) funds, 6) expertise and knowledge, and 7) laws and regulation.

The collected data from the questionnaire was sufficient to draw a comprehensive understanding of the extent of considering risk reduction and assessment in the current spatial planning practices in Egypt. The content analysis of the questionnaire by ATLAS.ti 8 was used to quantitatively analyse the codes and explore the patterns in data. However, the literal meaning will be lost to some extent.

6.1.2. Objective 2: Analysing the worst observed urban flood event in Alexandria

Mapping the flood depth and distribution revealed critical levels in several locations, especially within the voids of the built-up area since water is most likely to be trapped with artificial obstacles. Furthermore, water within the flat lowlands in the southeastern parts of the city was distributed. This leaves a considerable portion of population and assets (buildings, roads, agriculture lands) exposed to the dangers of the flood. Accordingly, the highest flood depths emerge in El-Montazah neighborhood.

Open-source data (rainfall: PERSIANN-CCS, DEM: ALOS WORLD 3D, landcover: Sentinel classification) and model (RRI) were used to simulate the flood in Alexandria. The modeler used data with the highest accuracy and resolution as possible within the available free resources to have accurate results. Though the model was validated using pictures for the simulated event, the validation points were not sufficient to cover the entire study area. However, the resulted simulation gave an acceptable indication for the flood depth distribution in the study area.

6.1.3. Objective 3: Objective assessment of the vulnerability of Alexandria city to urban flood hazard

The construction of suitable indicators for assessing the urban flood vulnerability are mainly the outcome of relevant literature as well as the experts' knowledge with the local context. Statistically irrelevant indicators are to be recognized by PCA, thus, 20 indicators were eliminated accordingly. This provides an objective and systematic process to identify suitable indicators, which will increase the transparency related to the results, and the decision that follows.

The available institutional databases for planners were found to be sufficient for constructing the needed indicators to conduct a multidimensional and an objective vulnerability assessment using PCA. Thus, the results gave the expected vulnerability assessment that can be used for decision making. Since PCA was attributed to communication difficulties, mapping the individual components was found to appropriate to increase the clarity. The results revealed that most of the highest vulnerable Shykha units are in El-Gomrok neighborhood, which is the oldest neighborhood in Alexandria.

6.1.4. Objective 4: Providing an informative risk assessment for spatial planning in Egypt

The analyses of risk, both statistical and mapping, revealed the variations of risk on the level of Shyakha units, as well as the level of neighborhoods. Conducting the analysis on the level of the Shyakha units was suitable to reveal most of the risk variations; however, analysis on smaller levels (city's blocks or buildings) will narrow down the scope of the needed intervention to precise locations. El-Montazah neighborhood contains units with the highest deviations of risk values from the mean risk in the study area. Furthermore, the very high risk in the study area is a combination of the middle values of hazard and vulnerability.

6.2. Recommendations and future research

The mainstreaming of risk reduction into spatial planning practices in Egypt requires the adoption of the represented strategies by Wamsler (2014, 2016) and their related activities, which have been followed by several organizations worldwide. The mainstreaming should directly correspond and consider the 7 groups of aspects, which resulted from the spatial planners' opinion about the obstacles of mainstreaming and the possible improvements. Accordingly, NSCDMDRR recommendations in 2010 should be reviewed to align with these strategies, as well as the recent political, socio-economic, and scientific changes. GOPP should undertake the responsibility of comprehensively harmonize and integrate the sectorial risk reduction plans.

Multiple risk assessments should be considered and emphasized while considering a multidimensional vulnerability assessment. Nevertheless, the hazard information needs to be provided, localized, and harmonized. The implementation of objective methods is needed in order to increase the transparency and clarity of the results and their subsequent decisions, and thus, vulnerability assessment using PCA can serve as an objective and systematic approach in that endeavour. This will provide planners with the information needed to design proper planning interventions (land use planning, construction codes etc.), which strive for risk reduction.

A follow-up study is needed, of which comparing between the deductive and the inductive approaches in terms of planners and decision-makers preferences. Furthermore, a weighting scheme for the importance of the vulnerability dimensions should be based on consultation with decision-makers.

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8. ANNEXES

8.1. Annex 1: The questionaire

Risk Assessment and Spatial Planning Practice in Egypt

I am Aly Rashad, a MSc. student in the ITC, University of TWENTE (UT), The Netherlands. My thesis topic is, **"Improving Vulnerability Assessment to Mainstream Risk Reduction in Spatial Planning for Alexandria City in Egypt"**. The risk assessment will be conducted for the **urban flood** context in the city that occurs due to extreme rainfall events.

This survey will collect data from **planning experts** in **Egypt** in order to develop a better understanding of the extent of vulnerability and risk assessments usage in the **current spatial planning practices in Egypt**, as well as the obstacles, which could hinder their usages. The results of the survey will help to describe the current relationship between spatial planning and risk assessment and investigating the optimal methods for communicating the assessment's results for decision-making procedures in the spatial planning process.

Kindly be noted that this survey consists of **60** questions. **half of the questions are in the form of open questions**, while the other half is as multiple choices. The survey will need between **45 to 60 minutes** to be taken and it only can be done in **one session**.

- Do you consent to the use of the provided information for research purposes?Y/N
- Do you consent to disclose your name?Y/N

1) PARTICIPANT'S INFORMATION	
Name	
Professional position (if applicable)	
Academic position (if applicable)	
Institutional affiliation	
Other Institutional affiliation (2) (if applicable)	
Personal email address	
Institutional email address (if applicable)	
Phone number	
Kindly shortly describe your academic and professional background in keywords	

2) HAZARD INFORMATION ACQUIRING AND MODELING	
2.1	**Hazard exposure perception is different based on the academic and professional background; thus, please define exposure based on your perception and understanding?**
2.2	**To what extent does urban flooding is being recognized as an important hazard in the current spatial planning practices in Egypt?**

1) Never	2) Very Rarely	3) Rarely	4) About Half the Time	5) Usually	6) Always

2.3 In your opinion, what are the main causes (physical/socio-economic) for urban flooding in Egypt that lead to severe damages or losses?	
2.4 Which cities or regions in Egypt do urban flooding represent a major concern?	
2.5 Are flood modeling experts being involved in the planning process? if No skip (2.5).	
Yes	NO
2.6 Do flood modeling experts provide planners with the needed up to date urban flood models or maps?	
Yes	NO
If yes, can you give an example of what they provide?	

2.7 To what degree are the following sources being used mostly for extracting urban flood information?

	1) Never	2) Very Rarely	3) Rarely	4) About Half the Time	5) Usually	6) Always
1) Literatures						
2) Geotechnical maps encyclopedia						
3) Topographic maps 1: 100,000						
4) Topographic maps 1: 50,000						
5) Topographic maps 1: 25,000						
6) Digital Elevation Models (SRTM) 30m						
7) Digital Elevation Models (ASTER) 30m						
8) Digital Elevation Models (ALOS World 3D) 30m						
9) Satellite Images (Sentinel)						
10) Satellite Images (LANDSAT)						
11) Satellite Images (MODIS)						
12) Satellite Images (SPOT)						
13) Other (please mention)						

2.8 Which of the following criteria is being used for urban flood hazard assessment? Multiple selections are applicable.

1) Flood depth
2) Spatial distribution (location)
3) Frequency
4) Return period
5) Flood duration
6) Flood speed
7) Other (please mention)

2.9 When is urban flood being considered as a hazard in terms of the following? Please mention the minimum value.	
1) Flood depth	
2) Spatial distribution (location)	
3) Frequency	
4) Return period	
5) Flood duration	
6) Flood speed	
7) Other (please mention)	

2.10 As far as you know, are any numerical models or simulations used for the hazard assessment in spatial planning practices in Egypt? Please give an example where and when numerical models have been used and by whom.			
2.11 To what extent do you think that the used numerical models are sufficient?			
1) Not Sufficient	2)Low Sufficiency	3)Moderate Sufficiency	4)High Sufficiency
2.12 To what extent do you think that the used hazard assessment is sufficient?			
1) Not Sufficient	2) Low Sufficiency	3) Moderate Sufficiency	4) High Sufficiency
2.13 What shortcomings or gaps do you perceive in the current hazard assessment practices (methods/data/modeling)?			
2.14 How is flood hazard usually being communicated to you, in spatial planning projects in Egypt?			
2.15 To what extent do you think that the communication methods of the flood hazard information to you is sufficient?			
1) Not Sufficient	2)Low Sufficiency	3)Moderate Sufficiency	4)High Sufficiency
2.16 In your opinion, what are the reasons that hinder the effective communication of hazard information for spatial planning practices in Egypt?			
2.17 in your opinion, how can urban flood hazard's communication be improved in order to support spatial planning practices in Egypt?			

3) VULNERABILITY ASSESSMENT					
3.1 Vulnerability perception is different based on the academic and professional background; thus, please define risk based on your perception and understanding?					
3.2 To what extent is vulnerability assessment being used as one of the planning tools					
1) Never	2) Very Rarely	3) Rarely	4) About Half the Time	5) Usually	6) Always
3.3 What is the current approach for conducting a vulnerability assessment to support spatial planning practices in Egypt?					

3.4 To what extent are social indices being used in the vulnerability assessment?					
1) Never	2) Very Rarely	3) Rarely	4) About Half the Time	5) Usually	6) Always
1) Never	2) Very Rarely	3) Rarely	4) About Half the Time	5) Usually	6) Always
3.5 Which social indices are being used usually for the vulnerability assessment in spatial planning practices in Egypt? Please mention them if possible.					
3.6 To what extent are economic indices being used in the vulnerability assessment?					
1) Never	2) Very Rarely	3) Rarely	4) About Half the Time	5) Usually	6) Always
3.7 Which economic indices are being used usually for the vulnerability assessment in spatial planning practices in Egypt? Please mention them as possible.					
3.8 To what extent physical indices being used in the vulnerability assessment?					
1) Never	2) Very Rarely	3) Rarely	4) About Half the Time	5) Usually	6) Always
3.9 Which physical indices are being used usually for the vulnerability analysis in urban projects in Egypt? Please mention them as possible.					
3.10 To what extent are weights assigned to the selected indices?					
1) Never	2) Very Rarely	3) Rarely	4) About Half the Time	5) Usually	6) Always
3.11 What methods are usually used to determine indices' weights?					

3.12 To what extent the following data sources contribute to the development of vulnerability indices?						
	1) Never	2) Very Rarely	3) Rarely	4) About Half the Time	5) Usually	6) Always
1) Census data from the Central Agency for Public Mobilization and Statistics (CAPMAS)						
2) Physical geodatabase from General Organization for Physical Planning (GOPP)						
3) Other (please mention)						

3.13 To what extent data from the following sources are sufficient for developing vulnerability indices?				
	1) Not Sufficient	2)Low Sufficiency	3)Moderate Sufficiency	4)High Sufficiency
1) Census data from the Central Agency for Public Mobilization and Statistics (CAPMAS)				
2) Physical geodatabase from the General Organization for Physical Planning (GOPP)				
3) Please mention other data sources that could improve data sufficiency				
3.14 What other data sources do you suggest?				

3.15 To what extent do you think that the followed methods of the risk assessment are sufficient?

1) Not Sufficient	2) Low Sufficiency	3) Moderate Sufficiency	4) High Sufficiency

3.16 What shortcomings or gaps do you perceive in the current vulnerability assessment practices (methods/data)?

3.17 What shortcomings or gaps do you perceive in the current vulnerability assessment practices (methods/data)?

3.18 How is vulnerability usually being communicated to you, in spatial planning projects in Egypt?

3.19 To what extent do you think that the communication methods of the <u>vulnerability</u> information to you is sufficient?

1) Not Sufficient	2)Low Sufficiency	3)Moderate Sufficiency	4)High Sufficiency

3.20 In your opinion, what are the reasons that hinder the effective communication of vulnerability information for spatial planning practices in Egypt?

3.21 In your opinion, how can vulnerability information communication be improved in order to support spatial planning practices in Egypt?

3.22 If there are any specific analyses for vulnerability information that are usually used for supporting or making decisions in spatial planning practices, please mention it?

4) RISK ASSESSMENT

4.1 Risk perception is different based on the academic and professional background; thus, please define risk based on your perception and understanding?

4.2 What are the used methods for estimating risk in the current spatial planning practices in Egypt?

4.3 Do you consider hazards' risk reduction as one of the planning problems in Egypt?

Yes	NO

4.4 Do you consider hazards' risk reduction as one of the planning goals?

Yes	NO

4.5 To what extent is risk being considered in <u>problems'</u> identification for spatial planning projects?

1) Never	2) Very Rarely	3) Rarely	4) About Half the Time	5) Usually	6) Always

4.6 To what extent is risk reduction or mitigation being considered in <u>goals'</u> identification for spatial planning projects?

1) Never	2) Very Rarely	3) Rarely	4) About Half the Time	5) Usually	6) Always

4.7 To what extent is risk being considered in identifying the planning priorities?

1) Never	2) Very Rarely	3) Rarely	4) About Half the Time	5) Usually	6) Always

4.8 Exposure is one of the inputs for risk assessment, to what extent each of the following assets' exposure being estimated for spatial planning decision support ?

	1) Never	2) Very Rarely	3) Rarely	4) About Half the Time	5) Usually	6) Always
1) Number of people						
1. Number of buildings						
2. Area of cropped lands						
3. Length of roads						
4. Length of infrastructure						
5. Number of cars						
6. Other (please mention)						

4.9 As loss is one of the inputs for risk assessment, to what extent each of the following loss values being estimated?

	1) Never	2) Very Rarely	3) Rarely	4) About Half the Time	5) Usually	6) Always
a) Direct loss due to physical damage to assets						
b) Loss of income or livelihood due to business interruption						
c) Loss of lives						
d) Other (please mentio						

4.10 What shortcomings or gaps do you perceive in the current risk assessment practices(methods/communication)?

4.11 How can risk assessment be improved for better integration into spatial planning practices?

4.12 How is the risk usually being communicated to you, in spatial planning projects in Egypt?

4.13 To what extent do you think that the communication methods of the risk information to you is sufficient?

1) Not Sufficient	2) Low Sufficiency	3) Moderate Sufficiency	4) High Sufficiency

4.14 In your opinion, what are the reasons that hinder the effective communication of risk information for spatial planning practices in Egypt

4.15 In your opinion, how can risk information communication be improved in order to support spatial planning practices in Egypt?

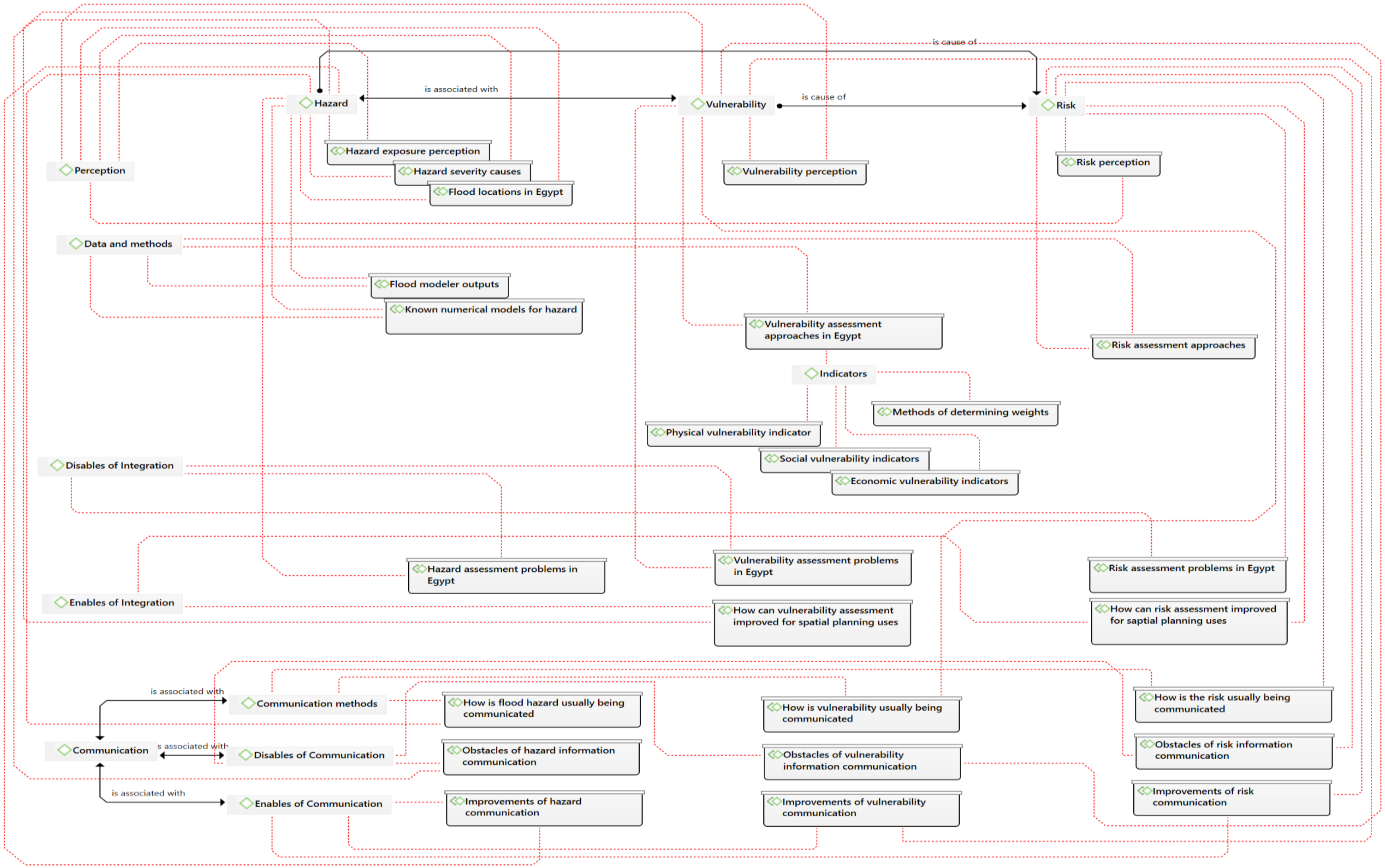
4.16 If there are any specific analyses for risk information that are usually used for supporting or making decisions in spatial planning practices, please mention it?

5) FINAL REMARKS	
5.1	**Besides risk information, what other information can be used for decision marking in spatial planning to reduce urban flooding risk?**
5.2	**If you have any final remarks regards the topic, please mention it**

Finally, My thesis focuses on improving vulnerability assessment, which is mostly conducted for the risk assessment phase and under the risk management processes. This improvement will be accomplished by utilizing the data which are well provided for the spatial planning process, especially census information from the Central Agency for Public Mobilization and Statistics (CAPMAS) and physical geodatabase from the General Authority for Urban Planning (GOPP). Consequently, the improved risk assessment will be mainstreamed in the planning process through two aspects. Firstly, risk reduction as the primary goal from the risk management process needs to be incorporated into planning goals. Secondly, support the planning process by the improved risk assessment in the problem analyses phase, which will provide a better perception of the current status of the community problems and priorities, and therefore, identifying the proper planning interventions.

- Would you like to receive the survey results after the thesis is being approved?Y/N
- Would you like to receive the final thesis after it is being approved?Y/N

8.2. Annex 2: The coding scheme



8.3. Annex 3: The prepared Indicators (colored cells refer to the used indicators)

	Indicator Code	Indicator Name	Data source	Description	Used Indicators in PCA
Physical	BLDRSDNO	Number of residential buildings per Sq. km	GOPP	Number of residential buildings divided by Shyakha area Sq. km	
	BLDINDCOMNO	Number of industrial and commercial buildings per Sq. km	GOPP	Number of industrial and commercial buildings divided by Shyakha area Sq. km	
	BLDSRVNO	Number of services buildings per Sq. km	GOPP	Number of services buildings divided by Shyakha area Sq. km	
	BLDLWRISNO17	Number of low rise buildings 2 floors and less per Sq. km	GOPP	Number of low rise buildings 2 floors and less divided by Shyakha area Sq. km	
	BUMAKSHFT17	Number of makeshift Buildings per Sq. km per Sq. km	CAPMAs Censes 2017	Number of makeshift buildings divided by Shyakha area Sq. km	
	BLDLWQUNO17	Number of low quality buildings per Sq. km	GOPP	Number of low quality buildings divided by Shyakha area Sq. km	
	BLDMEDQUNO17	Number of medium quality buildings per Sq. km	GOPP	Number of medium quality building divided by Shyakha area Sq. km	
	BLDBRGWLL	Number of bearing walls buildings per Sq. km	GOPP	Number of bearing walls buildings divided by Shyakha area Sq. km	
	BUNCNAT17	Number of buildings not connected to natural gas per Sq. km	CAPMAs Censes 2017	Number of buildings not connected to natural gas divided by Shyakha area Sq. km	
	BUNCSNT17	Number of buildings not connected to sanitation per Sq. km	CAPMAs Censes 2017	Number of buildings not connected to sanitation divided by Shyakha area Sq. km	
	BUNCWAT17	Number of buildings not connected to Water per Sq. km	CAPMAs Censes 2017	Number of buildings not connected to water divided by Shyakha area Sq. km	
	BUNCELCT17	Number of buildings not connected to Electricity per Sq. km	CAPMAs Censes 2017	Number of buildings not connected to electricity divided by Shyakha area Sq. km	
	LUGRNSK	Ratio of green spaces area	GOPP	The total of gardens land use divided by Shyakha area Sq. km	
	BUFAR	Built up area density	GOPP	The accumulative areas of building's floors divided by Shyakha area Sq. km	
	DSTHOSBK	Average distance to the nearest hospital in Km	Ministry of health (MOH)	Network analysis: origin distention coast matrix analysis	
Social	POPDENSK17	Population density	GOPP and CAPMAs Censes 2017	Total of population divided by Shyakha area Sq. km	
	AVERFAMSIZ17	Average family size	CAPMAs Censes 2017	Total of population divided by number of households in each Shyakha Sq. km	
	OCROW17	Overcrowding rate	CAPMAs Censes 2017	Number of family members divided by the number of rooms	
	NHHL2R17	Number of households living in two rooms and less per Sq. km	CAPMAs Censes 2017	Number of households living in two rooms and less divided by Shyakha area Sq. km	
	OldRent17	Number of households living in controlled rent units per Sq. km	CAPMAs Censes 2017	Number of households living in controlled rent units divided by Shyakha area Sq. km	

	OTYPRNT17	Number of households living in other rented units per Sq. km	CAPMAs Censes 2017	Number of households living in other rented units divided by Shyakha area Sq. km	
	NOFEM17	Number of females per Sq. km	CAPMAs Censes 2017	Number of females divided by Shyakha area Sq. km	
	NEA6517	Number of elderly population above 65 years old per Sq. km	CAPMAs Censes 2017	The sum of age groups above 65 divided by Shyakha area Sq. km	
	NCU517	Number of children below 5 years old per Sq. km	CAPMAs Censes 2017	The sum of population in the age groups less than 5 years old divided by Shyakha area Sq. km	
	DISABLED06	Number of disabled population per Sq. km	CAPMAS Censes 2006	Number of disabled population with body or mind disability divided by the Shyakha Area Sq. km	
	PRMSTUDNT	Number of students in primary schools per Sq. km	Ministry of Education (MOE)	Number of students in primary schools divided by the Shyakha Area Sq. km	
	PRIMEDU17	Number of population with basic education per Sq. km	CAPMAS Censes 2017	Sum of the population with primary school certificate and the residents with middle school certificate divided by the Shyakha area Sq. km	
	CANRDWRT17	Number of population who read and write but without education per Sq. km	CAPMAS Censes 2017	Sum of residents with cognitive education, Literacy classes and read and write without certificate divided by Shyakha area Sq. km	
	ILLTER17	Number of illiterates population per Sq. km	CAPMAS Censes 2017	Number of Residents with no education divided by Shyakha area Sq. km	
	ILLTERRR17	Illiteracy rate	CAPMAS Censes 2017	Number of illiterate residents divided by the number of population in education age	
	FORIGNER06	Number of foreigners per Sq. km	CAPMAS Censes 2006	Number of foreigners divided by Shyakha area Sq. km	
	NVRMRD17	Number of never married population per Sq. km	CAPMAS Censes 2017	Number of never married population divided by Shyakha area Sq. km	
	WIDOD17	Number of widowed population per Sq. km	CAPMAS Censes 2017	Number of widowed population divided by Shyakha area Sq. km	
	DIVORC17	Number of divorced population per Sq. km	CAPMAS Censes 2017	Number of divorced population divided by Shyakha area Sq. km	
	HHWOELECT17	Number of households connected to electricity per Sq. km	CAPMAS Censes 2017	Number of households connected to electricity divided by Shyakha area Sq. km	
	HHWOWATR17	Number of households connected to water per Sq. km	CAPMAS Censes 2017	Number of households connected to water divided by Shyakha area Sq. km	
	HHWOSWGE17	Number of households connected to sanitation per Sq. km	CAPMAS Censes 2017	Number of households connected to sanitation divided by Shyakha area Sq. km	
	FOODINS17	Food insecurity ratio	CAPMAS Censes 2017	The ratio of population the state of being without reliable access to a sufficient quantity of affordable, nutritious food.	
Econo	LURSDSK	Ratio of residential land uses	GOPP	Number of residential land uses divided by Shyakha area Sq. km	
	LUINDCOMSK	Ratio of industrial and commercial land uses	GOPP	Number of industrial and commercial land uses divided by Shyakha area Sq. km	

	LUSRVSK	Ratio of services land use area	GOPP	Number of services land use area divided by Shyakha area Sq. km	
	UNEMPOL06	Number of unemployed population per Sq. km	CAPMAS Censes 2006	Number of unemployed population divided by Shyakha area Sq. km	
	OSLBRFRC17	Number of populations outside the labor force per Sq. km	CAPMAS Censes 2017	Number of populations outside the labor force divided by Shyakha area Sq. km	
	DPNDRTIO06	Dependency ratio	CAPMAS Censes 2017	Number of populations outside the labor force divided by number of populations inside the labor force	
	EXTPOV17	Extreme poverty ratio	CAPMAS Censes 2017	The percentage of population who lives with lower than 1.25 USD daily	
	PRIMACT06	Number of population working in primary activities per Sq. km	CAPMAS Censes 2006	Sum of population who work in agriculture, fishing and mining divided by Shyakha area Sq. km	
	SERVOCCUACT06	Number of population working in public services per Sq. km	CAPMAS Censes 2006	population who are involved in food services, accommodation, scientific and technical activities, education, health, public administration, defense, social security, arts, creativity, activities, and others divided by Shyakha area Sq. km	
	TRANSCOMMACT06	Number of population working in transportation and communication activities per Sq. km	CAPMAS Censes 2006	Number of population who work in transport storage, utilities, communications and information divided by Shyakha area Sq. km	
	MANCONSTACT06	Number of population working in industrial and construction activities per Sq. km	CAPMAS Censes 2006	Population working in building, construction and manufacturing industries divided by Shyakha area Sq. km	
	SERVMONYACT06	Number of population working in economic services per Sq. km	CAPMAS Censes 2006	Population working in financial intermediation, insurance, trade, vehicle repair and support activities divided by Shyakha area Sq. km	
	SERVPRIVACT06	Number of population working for household services per Sq. km	CAPMAS Censes 2006	Number of population working for household services divided by Shyakha area Sq. km	
	ORGLOCRIGACT06	Number of population working in national and international organizations per Sq. km	CAPMAS Censes 2006	Number of population working in national and international organizations divided by Shyakha area Sq. km	
	RETRDPOP06	Number of retired population per Sq. km	CAPMAS Censes 2006	Number of retired population divided by Shyakha area Sq. km	
	OLDNOWORK06	Number of old population who cannot work per Sq. km	CAPMAS Censes 2006	Number of old population who cannot work divided by Shyakha area Sq. km	
	DISBLDNWRKR06	Number of disabled population who cannot work per Sq. km	CAPMAS Censes 2006	Number of disabled population who cannot work divided by Shyakha area Sq. km	
	HOUSWIFE06	Number of housewives who do not work per Sq. km	CAPMAS Censes 2006	Total number of dedicated housewives divided by Shyakha area Sq. km	
	STUDNOTWOR06	Number of student who do not work per Sq. km	CAPMAS Censes 2006	Number of student who do not work divided by Shyakha area Sq. km	
	WORWOPAYM06	Number of population who work without wage per Sq. km	CAPMAS Censes 2006	Sum of population who work for a family without a wage and the population who work without a wage for others divided by Shyakha area Sq. km	

8.4. Annex 4: The exposed assets