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Integration of flood risk assessment and spatial planning for disaster management in Egypt

Aly Esmaiel [a], Karim I. Abdrabo [b,c,*], Mohamed Saber [d], Richard V. Sliuzas [e], Funda Atun [e], Sameh A. Kantoush [d], Tetsuya Sumi [d]

[a] Urban Planning Consultant, UN-Habitat Egypt, Housing and Building Research Centre (HBRC), 87 Tahreer Street, 9th floor s– Dokki, Giza 1770, Egypt
[b] Department of City Planning, Faculty of Urban and Regional Planning, Cairo University, Giza 12613, Egypt
[c] Department of Urban Management, Graduate School of Engineering, Kyoto University, Kyoto 615-8245, Japan
[d] Disaster Prevention Research Institute (DPRI), Kyoto University, Kyoto 611-0011, Japan
[e] ITC Faculty Geo-Information Science and Earth Observation, University of Twente, P.O. Box 217, 7500 AE Enschede, the Netherlands

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ABSTRACT

Increasing flood risk due to rapid urbanization and climate change calls for improved integration between flood risk management and spatial planning processes to enhance the resilience of cities, including in Egypt. Although much work has been conducted on flood impact in Egypt, the gap in integrating flood risk assessment with spatial planning practices has not been discussed in academia. In practice, flood risk assessment is not mandatory for local-level spatial planning projects in Egypt, resulting in increased flood risk. This study examines the causes of this gap and proposes possible solutions that increase flood resiliency. A mixed-method approach was utilized based on a questionnaire survey with local stakeholders in academic and professional categories. The results reveal reasons for the gap, including issues related to the realization of the role of spatial planning in flood risk reduction, lack of coordination between the authorities responsible for developing the flood hazard maps and the spatial planning authority, availability and accessibility of the required data, and subjectivity of conducted flood analyses. Four key recommendations pertain to building an operational framework for integrating flood risk assessment in spatial planning, improving stakeholder awareness and collaboration, strengthening risk communication, and improving both quality and access to data. These measures will help to overcome the identified difficulties and enhance the integration between spatial planning and flood risk assessment, effectively increasing their flood resilience.

1. Introduction

Floods in cities with high population density may inflict considerable losses and damage. The Emergency Events Database (EM.-D.A.T.), compiled by the Centre for Research on the Epidemiology of Disasters (CRED), reveals that between 2010 and 2021, almost 10% of the global population was affected by floods, and a total of 57,498 people have died due to floods [14]. In Egypt, flooding is a significant hazard. Between 1990 and 2014, floods accounted for 45% of hazardous events, 45.1% of hazard-related deaths and 46.5% of average annual hazard-related losses in Egypt [13,24]. Between 1980 and 2010, approximately 262,864 Egyptians were affected by floods, including 1527 people who died, with the annual losses due to flooding totaling 1.342 billion USD [13]. Egypt is mainly exposed to floods, particularly flash and pluvial floods occurring in urban areas [39]. Global trends of rapid urbanization, population growth, economic development, and climate change significantly increase the exposure of many areas to natural hazards, particularly floods [2,44]. As a result, people, properties, and the environment will be at far greater risk in the future. Urban floods result from compounding hydrological and meteorological extremes, as well as human activities [21]. Changes in land use or land cover accompanied by urbanization can reduce the soil permeability, increase surface runoff, and overload drainage systems; consequently, the flood risk increases [60]. Hollis anticipated that floods might rise by a factor of ten due to extensive urbanization. The severity could be doubled for 100-year return periods or result in more significant floods if 30% of

* Corresponding author at: Department of City Planning, Faculty of Urban and Regional Planning, Cairo University, Giza 12613, Egypt.
E-mail addresses: aly.esmaiel@un.org (A. Esmaiel), m.karim.ibrahim@cu.edu.eg (K.I. Abdrabo), mohamedmd.saber.3u@kyoto-u.ac.jp (M. Saber), r.sliuzas@utwente.nl (R.V. Sliuzas), f.atun@utwente.nl (F. Atun), samehahmed.2n@kyoto-u.ac.jp (S.A. Kantoush), sumi.tetsuya.2s@kyoto-u.ac.jp (T. Sumi).

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roads become paved [19,43].

Spatial planning endeavors to cut the spatial link between hazards and the exposed assets, reduce the surfacewater runoff, and reduce the community's vulnerability. Accordingly, it utilizes different land-use planning and building regulation instruments to customize suitable structural and non-structural measures for risk reduction [1,56]. It is indispensable to integrate risk management with spatial planning [18,20,38,56]. In recent years, the importance of integrating Disaster Risk Reduction (DRR) and urban planning fields at the policy level was outlined internationally. The 2005 World Conference on Disaster Reduction (WCDR) in Kobe, Japan [16], the Sendai Framework for Disater Risk Reduction 2015–2030, the Rio + 20 World Conference in 2012, and the Intergovernmental Panel on Climate Change (IPCC) have all underlined the importance of considering disaster risk reduction, resilience, and climate risks in urban planning to attain sustainable development at different scales [20,37,53]. However, the literature confirms the separation of the two fields of risk reduction and planning practices, making achieving this integration a challenge. The reality is that, in general, the: "linkages between urbanization and disaster are weakly theorized and estimated [34], and often there is poor cooperation between risk management and spatial planning authorities worldwide [54–56]. Spatial planners might not perceive risk reduction as a planning goal; furthermore, communicating information between experts from both fields is hindered by the differences in their target groups, purposes, data sources, and their educational and professional backgrounds [56]. At the same time, general disaster studies neglect spatial planning (including for housing) as a vitally important risk reduction measure [40]. Additionally, each authority operates under a different institutional framework with its own operational methods, and their funds are allocated for different purposes [18,56]. Therefore, a general consideration of risk reduction within spatial planning practices is questionable, especially in low-income countries [52,53].

It is necessary to take a quick glimpse at the current regulatory frameworks in Egypt for flood risk assessment and management and spatial planning at different scales. Regarding flood risk, Egypt has no existing national flood laws [25]. However, it has flood-related policies and strategies across national and local levels, such as Egypt's National Strategy for Adaptation to Climate Change and DRM 2011 and its update in 2017, in addition to the national climate change strategy 2050 ([29,49]; also, [50]) refers to the Prime Minister's Decree No. 3185/2016 with regards to forming a national committee for crisis/ disaster management and DRR. The institutional framework of crisis/ disaster management and DRR in Egypt comprises a DRM system that is divided into four scale levels: national, governorate, city, and district. At national level, the Committee for Crisis and Disaster Management and the National Committee for Crisis and Disaster Management are the leading actors. They are responsible for delegating responsibilities to various entities for disaster management, developing contingency plans, reviewing national strategies and policies, and supervising different governmental institutions and organizations in disaster simulation exercises. At the governorate level, a high committee for managing crises and disasters is the leading entity for disaster risk management. It is responsible for forecasting disaster-related hazards, reviewing the resources for disaster management, formulating action plans for emergencies, coordinating volunteers' efforts and conducting awareness raising, and formulating a communication strategy. At city level, the sub-committee for disaster and crises management and the center of operations city level are the responsible entities. In out-of-control crises, the military is the main actor who provides the necessary support and leads all entities to reduce the disaster impact and support the recovery of the communities. Despite the existence of a regulatory framework for disaster risk management in Egypt, the analysis of three major flood disasters (in Sohag 1994, Sohag 1996, and Alexandria 2015) showed the lack of an early warning system, insufficient preparation, low public risk awareness, a weak emergency culture, low infrastructure capacity, and a relatively passive disaster response [10].

Regarding spatial planning, the regulatory framework consists mainly of the Ministry of Housing, Utilities & Urban Communities as the responsible body for urban development at all levels. It has two main sub-entities; (1) urban communities, which deals with all new urban communities, and (2) the General Organization for Physical Planning (GOPP) which deals with the existing communities. According to the plan making guidelines of both entites, neither flood managments plans, nor flood hazard maps, nor exposure maps are mandatorty.

Although the focus on urban planning and disaster risk reduction has increased after the Rio + 20 world conference and the Sendai Framework for Disaster Risk Reduction 2015-2030 (since it was the first major agreement of the post-2015 development agenda and provides the Member States with concrete actions to protect development gains from the risk of disaster), Egypt has encountered several disaster risk reduction challenges. First, local planning practices and flood risk assessment are separated at both the academic and professional levels [4,47,48]. In academia, 81 peer-reviewed articles were published from 1986 to 2021 discussing Egypt's flood risk representing only 0.24% of the published articles in the same field worldwide. A substantial increase in the research effort is highlighted by the fact that 80% of the papers have been published since 2014. However, no published research has discussed the link between spatial planning and flood risk assessment in Egypt [1,2,38]. At the professional level, isolation results from planning laws, regulations, guidelines, and spatial planning projects' Terms of Reference (TORs) documents, which define the tasks and duties required of a project contractor and highlight project background and objectives at a high level that does not consider risk reduction as a planning goal [4,18,47]. Accordingly, Egypt's current planning practices contribute little to risk reduction despite the growing global recognition of their role in this endeavor [18,47,50,56]. Second, flood risk assessment studies in Egypt are not standardized. Third, there is a lack of coordination between the authorities responsible for developing the hazard maps and those responsible for spatial planning [11,18,47,48]. Fourth, vulnerability assessments either focus on one dimension of vulnerability, mainly physical, or subjectively utilize a non-representative set of indicators [2,47] without a clear rationale for selecting indicators or applying weights to them [2,8,9,11,12,30,41].

This study aims to understand the barriers to integrating flood risk assessment and spatial planning in Egypt and identify possible solutions. The results can support planners and decision-makers from both disciplines at academic and practical levels to contribute more effectively to building flood-resilient communities.

2. Methodology

An expert survey was designed to acquire data to understand the barriers to integrating flood risk assessment components (flood hazard and flood vulnerability) and the possible solutions. Methodological triangulation was used to strengthen the results by combining quantitative questionnaires and qualitative interviews involving open-ended questions [5], as shown in Annexes 1 and 2. The questionnaire and interviews were conducted in 2020. Both data collection instruments contained questions according to three categories as follows:

- Data and methods
- Barriers to integration between flood risk assessment and spatial planning
- Necessary improvements to achieve integration

The Survey Monkey platform was used for the online questionnaires. It facilitated building the questions in suitable forms and provided various dissemination channels, such as e-mail and social media platforms. Additionally, the platform allowed respondents to complete the questionnaire in multiple sessions and allowed the administrator to download the response data in different formats. The Excel format was chosen as the best format to prepare the results. A quantitative analysis

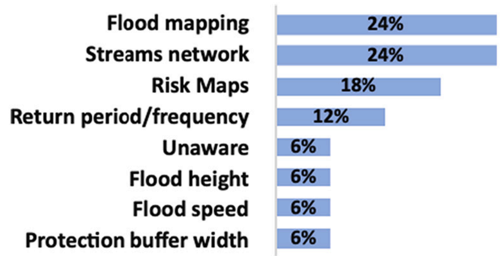

Fig. 1. Hazard experts' outputs for planners.

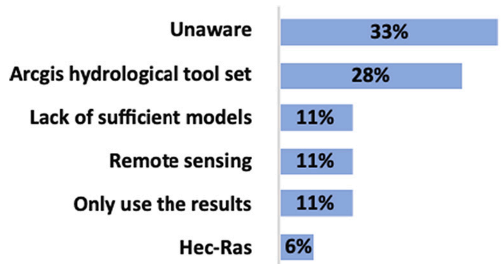

Fig. 2. Methods used by hazard experts.

Table 1
Importance of flood hazard parameters (in percent).

	Never	Very Rarely	Rarely	Half the Time	Usually	Always
1) Flood depth	14	18	14	14	36	5
2) Spatial distribution (location)	5	5	9	18	45	18
3) Frequency	10	24	14	19	24	10
5) Flood duration	5	25	15	25	30	0
6) Flood velocity	10	20	40	10	10	10

was performed for the closed questions to measure the frequency of response selection for each question [23]. Responses to each open question were presented in a separate Excel sheet and then converted to separate text documents. These were imported in ATLAS.ti 8 for qualitative analysis grouped on affiliation with the questionnaire's themes and categories. Additionally, the open-ended answers were condensed by coding: similar codes were assigned to similar responses, and unique codes were given to outlier responses. A code frequency analysis by ATLAS.ti 8 highlighted the points of consensus or difference between experts and individual responses. Together, the responses to closed and open questions provided a comprehensive picture of the barriers between the two fields in Egypt.

Targeted stakeholders have been defined as the individuals working in governmental, private, international organizations, and academic sectors with (1) disaster-related specialties or experiences. (2) presence of professional relationships with one of the authors to facilitate the communication process or those who had been recommended by one of the identified stakeholders using a convenience sampling technique [3]. Accordingly, thirty invitations were sent, and twenty-two experts responded and completed the questionnaire. They consisted of academicians and professionals in the fields of spatial planning (eighteen) and flood risk assessment (four). Although the number of respondents was quite small, it is worth mentioning that seven respondents were executives working with the Egyptian government and fifteen professors at Egyptian universities with vast experience in urban planning projects covering detailed, city and local, regional, and national scales.

The questionnaire was designed to be completed in between forty-five to sixty minutes. Two challenges were faced while conducting the questionnaires. First, considerable effort was needed to complete the questionnaire due to its length. Second, for five participants with limited knowledge of English, the questions and responses were orally translated to and from Arabic (orally) by one of the researchers.

3. Results

3.1. Flood hazard assessment practices within the spatial planning process

3.1.1. Commonly used data and methods to acquire flood hazard information

Planners utilize different data sources than hydrologists to acquire the required flood hazard information. The commonly used data sources to receive flood hazard information and the degree of their usage. Planners often obtain hazard information from the available literature, studies conducted by specialized institutions (Egyptian Environmental Affairs Agency, Egyptian Meteorological Authority, National Authority for Remote Sensing and Space), or hazard experts. According to 73% of the participants, hazard experts, including flood modelers, are rarely involved in the planning process. Planners widely use topographic maps to locate the main streams in the planning area; different topographic maps are used based on the planning scale. Open-source Digital Elevation Models (DEMs), such as SRTM, ASTER, and AW3D, were also used to extract the streams' network using 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 of hazard information.

Flood mapping and stream networks are the main outputs obtained from the hazard experts (Fig. 1). Planning experts appear to be unaware of flood models and are solely concerned about the results, according to 33% of the participants (Fig. 2). On the contrary, flood hazard experts

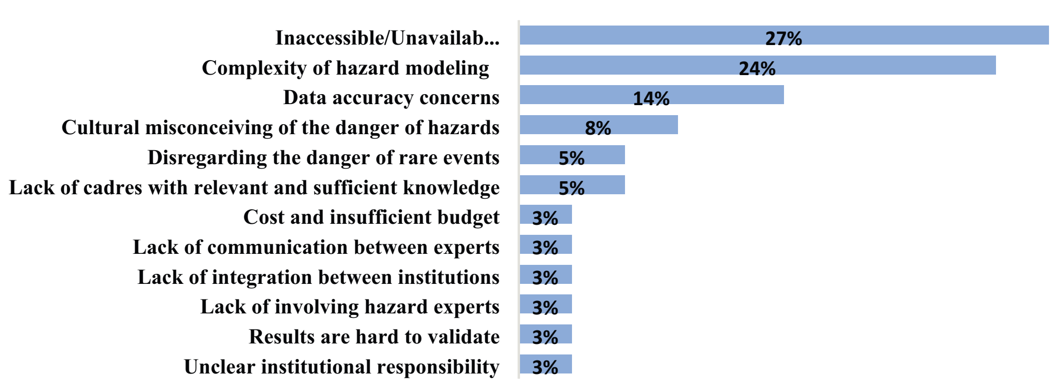

Fig. 3. Causes of disregarding the hazard information in the spatial planning practices in Egypt.

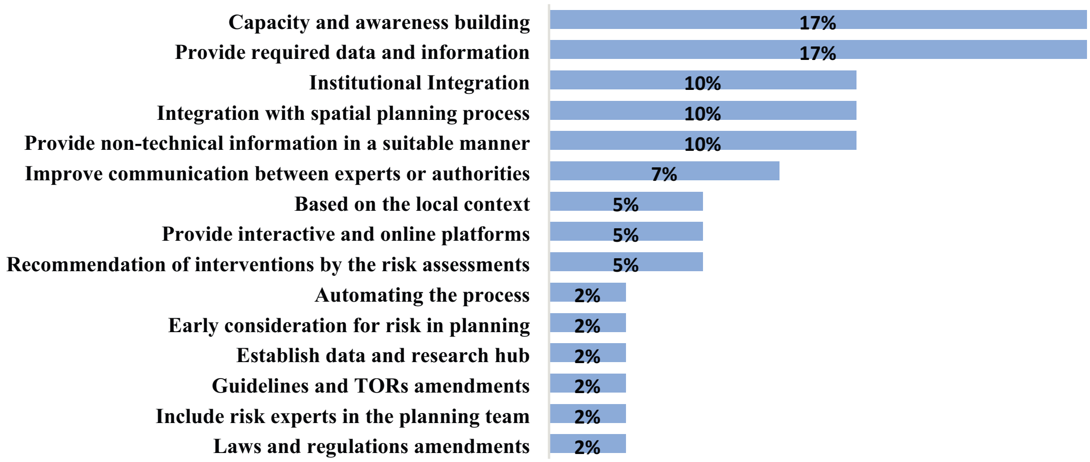

Fig. 4. Summary of the experts' recommended improvements to facilitate understanding of the hazard information for the planning process

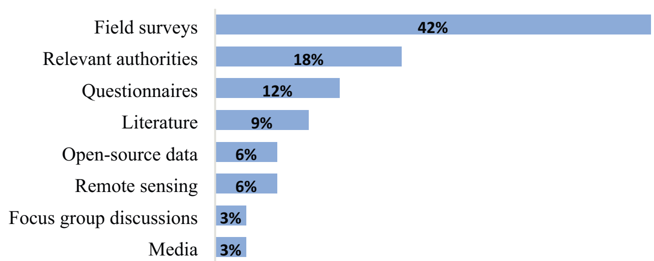

Fig. 5. Secondary data sources for flood vulnerability assessment.

have limited knowledge about how urban planning can reduce the flood risk besides avoiding it altogether.

The most crucial parameters to be determined for planners are the spatial distribution and flood depth (Table 1). According to 77% of the participants, although flood hazard experts are rarely directly involved, they mainly provide further information perceived as crucial and sufficient for planners. However, hazard experts usually recommend structural interventions rather than urban planning flood reduction tools in hazardous areas when they are involved.

3.1.2. Obstacles to considering hazard information in spatial planning

According to 41% of the experts, hazard data is unavailable, inaccessible, or inaccurate, particularly on the micro-scale. Moreover, 24% of the participants think that the complexity of hazard modeling prevents planners from conducting hazard assessments themselves. However, hazard experts are not usually involved in local planning projects because of the high cost of their services and because the projects' terms do not explicitly require a flood risk assessment. Thus, in the absence of flood hazard experts, flood hazard information is either neglected or may be misunderstood if and when it is considered (Fig. 3).

3.1.3. Possible improvements in the hazard assessment practices

Respondents were asked to consider several proposed improvements to current practices (Fig. 4). The need for institutional capacity building was most emphasized (17%), pointing to a need to better inform Egypt's decision-makers and citizens about urban flood threats. Furthermore, capacity building is needed for Egyptian planners and hazard experts to consider how to make better use of the provided hazard information in

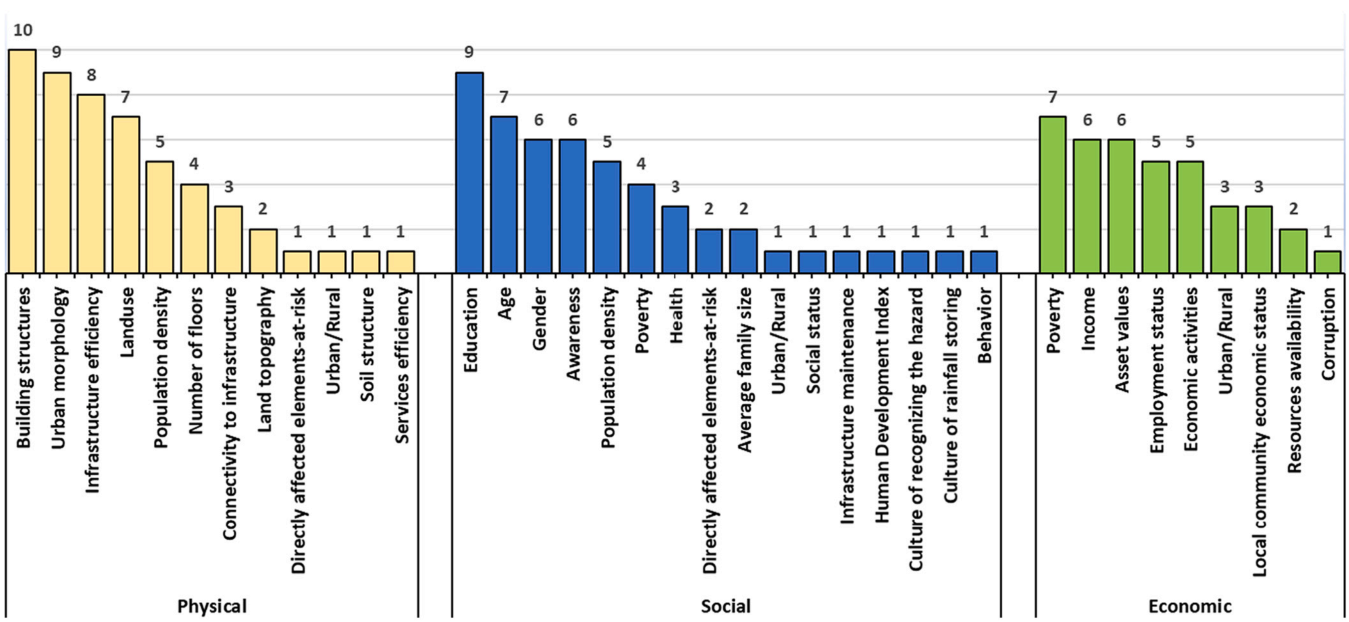

Fig. 6. Frequency of physical, social, and economic vulnerability indicators mentioned by experts.

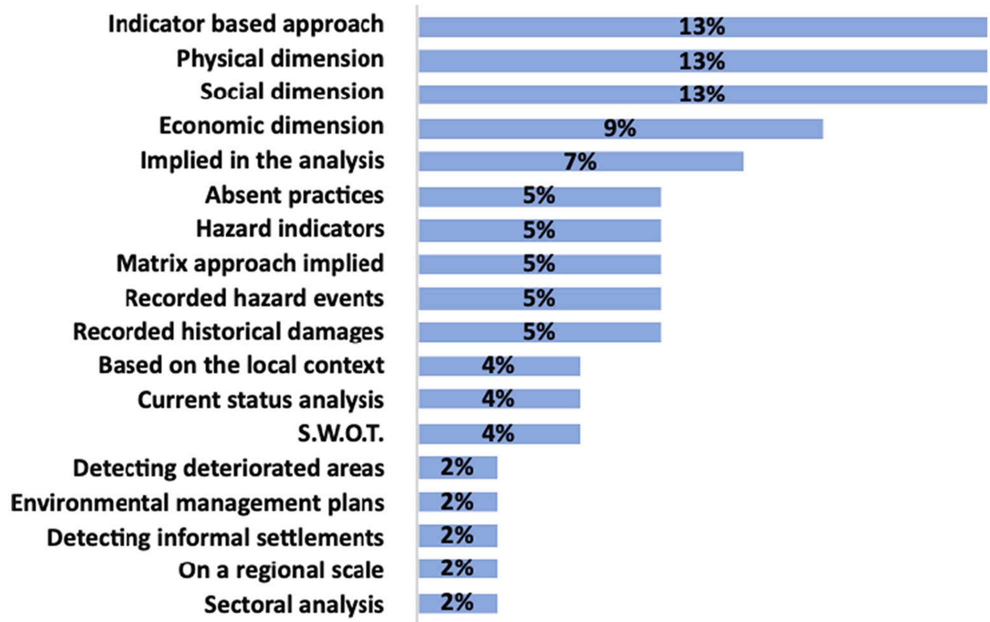

Fig. 7. Vulnerability assessment methods in Egypt.

Table 2
Participants' responses regarding the extent of use of weighted indicators.

Never	Very Rarely	Rarely	Half the Time	Usually	Always
9%	14%	9%	5%	50%	14%

planning and how to use urban planning mitigation measures for flood risk reduction. Improving the relevant data and ensuring it is accessible, creating an online interactive platform, introducing amendments to national laws and regulations that support institutional integration, and ensuring that the flood risk assessment is mandatory for local planning projects by enhancing the projects' terms of reference, were also highlighted.

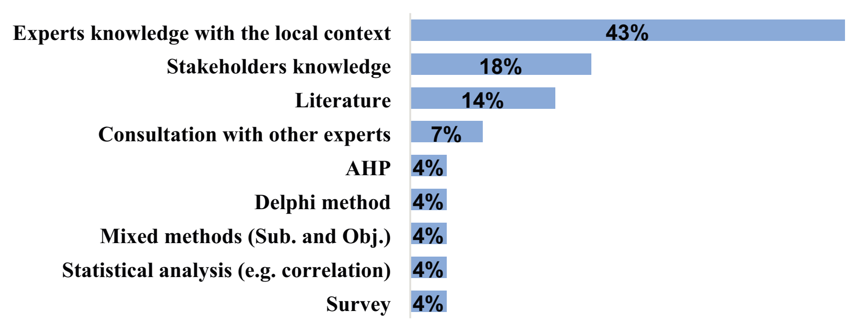

Fig. 8. Methods used for determining indicators' weights.

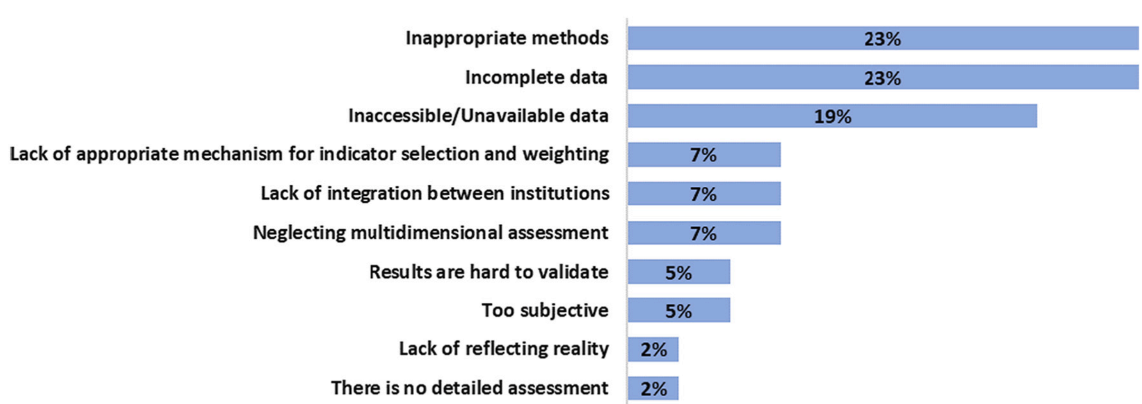

Fig. 9. Summary of relevant issues to be considered for determining vulnerability assessment in spatial planning.

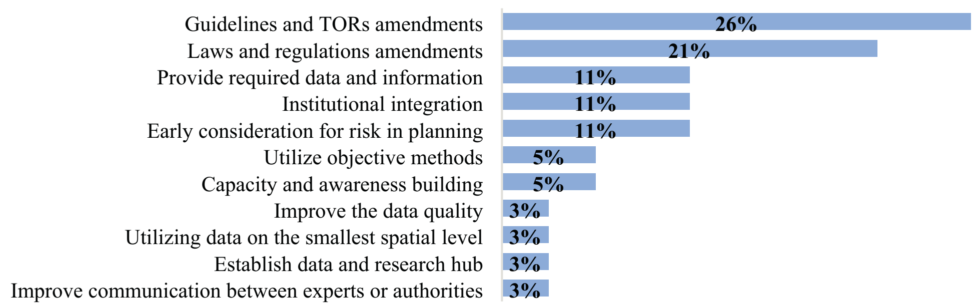

Fig. 10. Summary of the proposed improvements to enhance flood vulnerability consideration in spatial planning

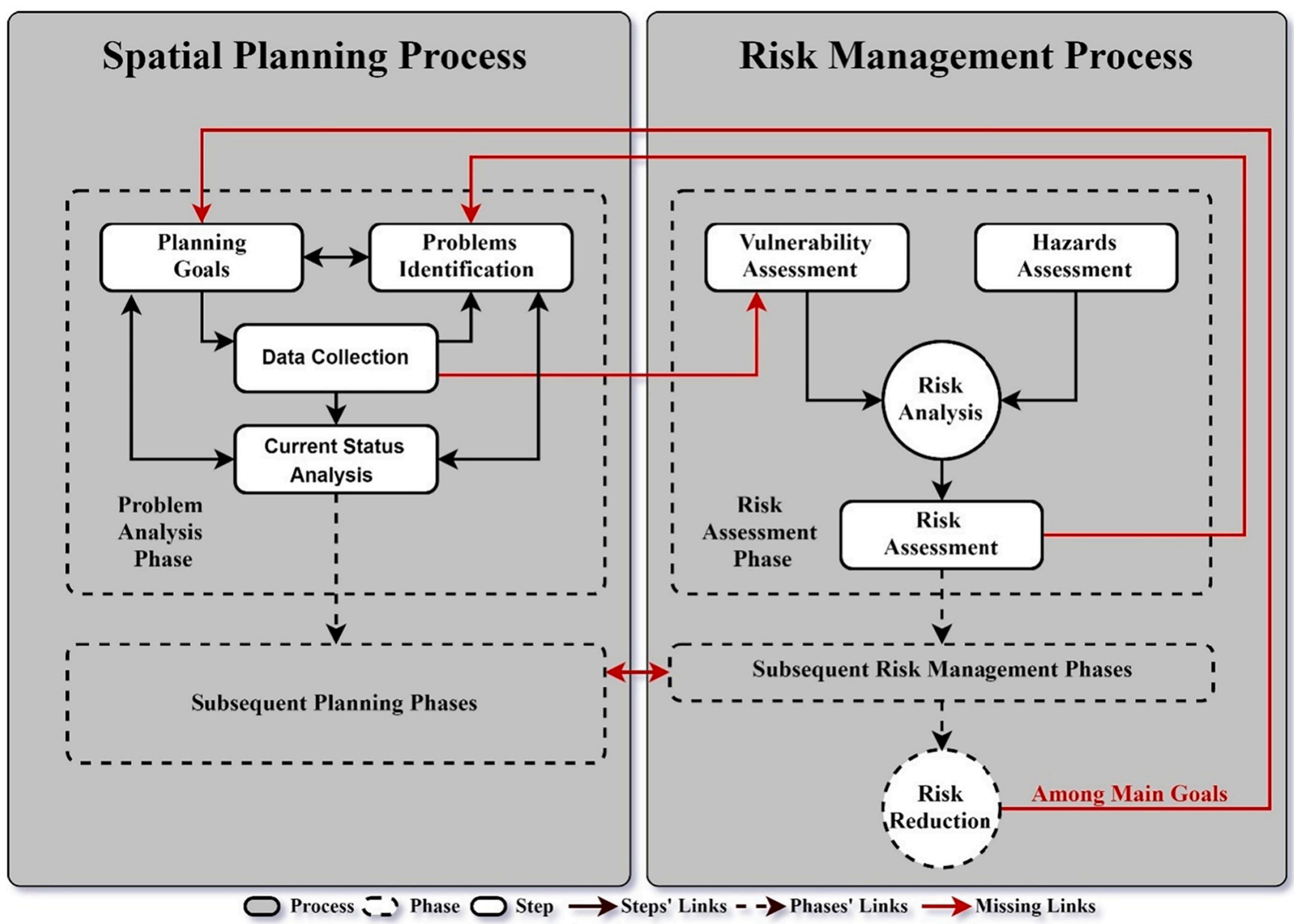

Fig. 11. Missing links (in red) between spatial planning and risk management, adapted from [17,55,57].
(For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

3.2. Flood vulnerability assessment practices within the spatial planning process

3.2.1. Commonly used data and methods

Vulnerability assessment is rare in Egypt's local planning projects, according to 64% of the experts. Planners mainly utilize census data from Central Agency for Public Mobilization and Statistics (CAPMAS) and physical elements' geo-databases from the General Organization for Physical Planning (GOPP) for the flood vulnerability assessment process, according to 81% of the participants. Other data sources are depicted in Fig. 5. According to 42% of experts, field surveys and questionnaires are usually used to update the planning inputs.

Vulnerability indicators are essential data for vulnerability assessment. The experts' perception of the crucial indicators in each vulnerability dimension resulted in a set of indicators. Regarding the physical vulnerability, the top four factors were building structure, urban morphology, infrastructure efficiency, and land use. At the same time, education, age, gender, and awareness were the top four social vulnerability indicators. Poverty rate, income, assets values, and employment status were the most important indicators of economic vulnerability. It is worth mentioning that there is a lack of consensus on crucial vulnerability indicators (Fig. 6).

The experts highlighted several methods for detecting vulnerable areas (Fig. 7). According to 13% of the experts, the frequently used

Table 3
Causes and possible improvements for the gap between spatial planning and flood risk assessment.

No.	Categories	causes	possible improvements
1	Laws, regulations, and ToRs	Relevant legislation and organizing frameworks do not require flood risk reduction from spatial planning since the capabilities of spatial planning in flood risk reduction are not well known. Thus, planning integration with relevant institutions for risk management is not supported. Accordingly, experts in risk reduction are not currently part of the planning process.	Legally obliging the relevant authorities to enforce risk reduction through amendments to existing requirements. In the USA, the Federal Emergency Management Agency (FEMA) identifies flood hazard areas, maps flood hazard areas, sets flood insurance rates, covers the risk, establishes design requirements for floodplain development, and provides funding for mitigation projects [46]. Also, Germany's Parliament adopted the "Flood Control Act" in July 2004 due to severe flood damage in August 2002 [28].
2	Lack of institutional integration	The weak links between the planning authorities (GOPP, Governorates) and sectoral risk management authorities (EEAA, civil defense, etc.) prevent mutual support. The same findings were presented by [55].	Developing memoranda of understanding between the different risk reduction institutions such as GOPP, CAPMAS, the Ministry of Agriculture, Water and Irrigation, and the Beach Protection Authority to facilitate knowledge transfer and data sharing, which is aligned with Wamsler and Brink [57]. The USA and the UK are two of the best practices in institutional integration and collaboration in the face of flooding risk. All levels of government are responsible for protecting citizens and property from flooding under the National Flood Insurance Program [51].
3	Lack of expertise and knowledge in both disciplines (urban planning and flood risk assessment)	The urban planners cannot independently model flood hazards. They are also unaware of the kind of data they require from the flood modelers (if they exist in the project). Similarly, hydrologists are not aware of the complexity of the urban system and cannot deliver their messages clearly to urban planners. They also focus on structural interventions and are unaware of the potential of urban planning tools in flood risk reduction.	Incorporating risk assessment in the planning practices will require new expertise and knowledge in the planning process [57,58]. Accordingly, capacity and awareness building are necessary for such a step. Several workshops in cooperation between urban planners and flood hazard experts need to be made, especially among the governmental authorities, to promote awareness of the importance of both fields for flood risk reduction. In the Netherlands, many leading universities are support multidisciplinary programs that combine spatial planning and hydrology, such as the IHE Delft and the University of Twente.
4	Funds	Since risk reduction is not a priority, it is a given that funds will be allocated elsewhere. Accordingly, the risk reduction will always be hampered by the lack of funds.	Though there were no specific suggestions to deal with funds, promoting the importance of risk reduction within the spatial planning process for the decision-makers will change their mindset to allocate more funds for this purpose [57,58]. One of the best practices for funding flood projects is the EU Floods Directive (2007/60/EC) which provides an opportunity for supporting various projects for reducing the flood risk in the EU, such as FREEMAN, IMRA, and URFlood funding initiative [31].
5	Communication	Poor communication hampers exchange plans, knowledge, experience, data collection and management. Thus, a conflict might occur between the sectoral plans and the spatial plans, which aligns with the findings of Wamsler [55].	Non-technical information is preferred for communication, especially for hazard information. It was recommended as the basis for communication to reduce the knowledge gap between the risk and planning experts [1,39,55]. Participants proposed to disseminate the results in an online interactive platform to increase the transferability of the information to different factors. Flood awareness and risk communication techniques have been widely adopted by European countries such as France, the UK, Germany, Luxembourg .. etc. [7].
6	Data	Scarcity, inaccessibility, inaccuracy, unsuitability, and scale-related issues of relevant data are all merely reflections of the other aspects of a hindrance (Fig. 11). The authorities responsible for hazard data collection do not acknowledge the planning requirements to adequately support the risk reduction by	Provision of the required data to conduct risk assessment within the planning process, including hazard and vulnerability information, is necessary. Furthermore, the participants emphasized: (1) improving the quality and the structure of the data to save time for

(continued on next page)

Table 3 (*continued*)

No.	Categories	causes	possible improvements
		collecting and providing the required information.	preparation and processing; (2) improving the accessibility of the data by establishing an online research and data hub; and (3) improving the integration between the relevant authorities,. Thus, the planners will focus mainly on the process; this aligns with the findings of previous studies [45]. In this context, the availability of open Spatial Data Infrastructure (SDI) has several advantages: SDI will increase the harmony and the accessibility of the data needed for risk assessment; it will also facilitate the flow of information between the relevant authorities and increase communication capacity [35,45]. In the UK, the relevant responsible agencies communicate the data related to flood risk and publicly share it through the governmental flood portal [15].
7	Methods	The risk assessment conducted by urban planners, including hazard and vulnerability assessments, follows subjective approaches that are hard to validate, owing to the lack of hazard information and relevant expertise. 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 significant improvement across the previously mentioned problems to support its success.	Following Karlberg and Nilsson [22], participants agreed that implementing objective methods is indispensable to ensure transparency. Moreover, they emphasized the early incorporation of risk assessment in the planning process and recommended the exact outcome [17]. Multiple risk consideration is widely highlighted in the literature [18,58], which the participants also emphasized. Additionally, participants recommended utilizing data on the micro-scale level to represent the spatial variations better, as highlighted by different studies [42,59]. Regulating the process will improve its harmonization for comparability and possible automation. Nevertheless, it might hinder creative thinking when dealing with exceptional cases [22].

method for flood vulnerability assessment is through indicators for either a single dimension or multiple dimensional vulnerability assessments. The most used vulnerability dimensions were physical and social, each totaling 13%, whereas the economic dimension was only 9%. The indicators are usually selected and weighted based on literature, subjective experts' knowledge of the local context, stakeholder participation, and available data. Most experts usually weigh the indicators to represent the relative importance of each indicator (Table 2). About 75% of the participants use experts' knowledge or literature to assign weights to the indicators. Tools such as AHP, Delphi, correlation analysis, or surveys are utilized to increase the objectivity of selecting and weighting the indicators (Fig. 8).

3.2.2. *Obstacles in considering flood vulnerability assessment in the spatial planning process*

According to 23% of the participants, the current methods for flood vulnerability assessment are inappropriate for four main reasons:

- Multiple dimensions of vulnerability are neglected.
- Regarding the indicator-based approach for flood risk assessment, indicators' weightings and selection are subjective and lack a scientific basis.
- The data is usually incomplete and requires considerable processing to be used or inaccessible; consequently, the assessment results are challenging to validate.
- There is a lack of integration between relevant authorities and institutions (Fig. 9).

3.2.3. *Possible improvements in vulnerability assessment practices*

The standardization and enhancement of the current planning guidelines and Terms of Reference, utilizing objective methods for selecting indicators and weightings, considering the multidimensional indicators, and providing the required data for flood vulnerability assessment by supporting the institutional integration are the most important recommendations for improving flood vulnerability assessment in Egypt (Fig. 10).

4. Discussion

The results from the quantitative and qualitative analyses are all mutually consistent and can be considered valid [33]. A striking feature of the experts' responses is that they had no unified definitions of key terms such as hazard, vulnerability, and risk. Though clear definitions for these concepts would help to establish a shared view and facilitate risk communication, it is apparently challenging to reach standard definitions that bridge different disciplines, as is also found elsewhere [22,57].

4.1. *Leading causes and possible improvements of the gap between spatial planning and flood risk assessment*

Risk assessment can provide spatial planning with a necessary tool for analyzing risk and making decisions accordingly. However, in the Egyptian context, risk reduction is currently not reflected in the planning outputs owing to many missing links between spatial planning and risk management (Fig. 11).

Thus, for several reasons, flood risk assessment is not incorporated within the spatial planning process for risk reduction [10,11]. The gap in integrating flood risk assessment in spatial planning is present in the Egyptian context and several other countries [6,36,59]. According to the respondents, these reasons and possible solutions can be grouped into seven interrelated categories (Table 3). The propositions for improvements thoroughly spanned methods, data, and communication, whereas limited and generic recommendations were given for the other aspects. The capacity and awareness building, providing the needed data for spatial planning and flood risk assessment, enhancing the institutional

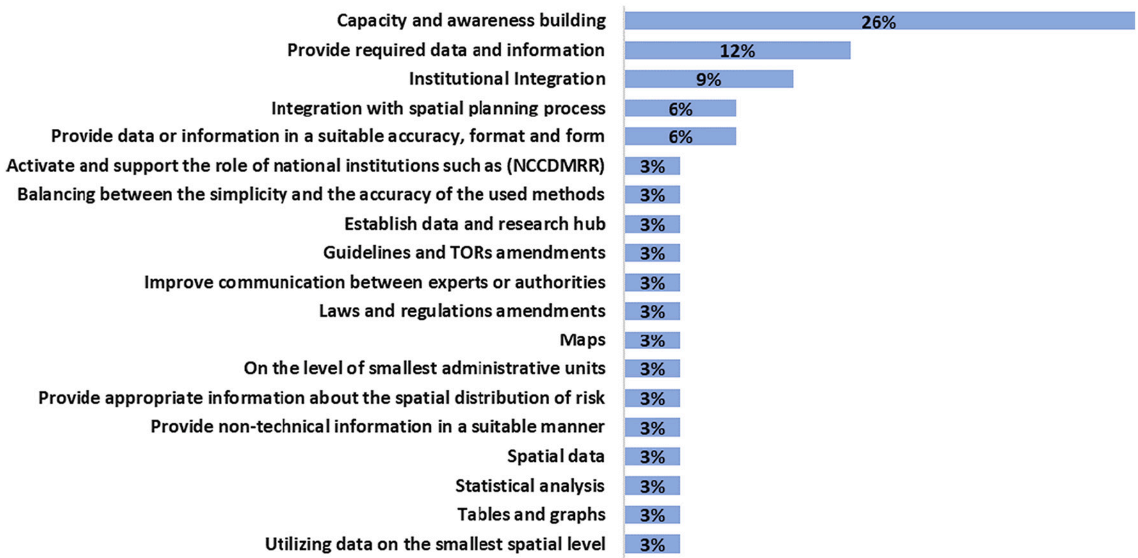

Fig. 12. Overview of the suggested improvements for communicating risk information

integration for transferring and sharing knowledge and information, and obliging the relevant authorities to integrate the risk reduction within the current spatial planning process through laws, regulations and ToRs amendments were the top four suggested improvements. There are also 15 others with much lower levels of support (Fig. 12).

5. Conclusion

The study has investigated the barriers to integrating flood risk assessment and spatial planning in Egypt and identified possible solutions. Our analysis revealed the discontinuity between current spatial planning and flood risk management on policy, academic and professional levels in Egypt. This conclusion has been aligned with several publications, such as the case of China [26,27]. At the same time, some of the high-income countries were found to have a connection between spatial planning and flood risk management but with some challenges in implementation as in the Netherlands [32].

We adopted a mixed-method approach to explore the causes behind the challenges in integrating flood risk assessment and spatial planning and identify means to overcome these difficulties. In Egypt, no previous research has focused on the gap in the successful integration of flood risk assessment and spatial planning, which is crucial for achieving the highest level of risk management. The results revealed that there is currently a lack of consideration for risk reduction in spatial planning practices in Egypt. Thus, risk assessment is not currently underutilized as a planning tool. Most experts' perceptions of key risk management concepts (hazard, vulnerability, and risk) is unclear, and they have a poor understanding of the connections between risk reduction and planning. Additionally, risk communication is inconsistent and hazard information scarce. Despite this, the available data for planning purposes (e.g., CAPMAS: census, GOPP: physical geo-database) is sufficient to perform vulnerability assessment for flooding, though the planning methods for flood risk (GSA, SWOT) are subjective and insufficient to analyze and fully understand risk. Therefore, the inclusion of flood risk assessment in spatial plan preparation is essential.

Seven main categories of obstacles to integration between flood risk assessment and spatial planning have been identified. Seven important recommendations for enhancing flood risk reduction (FRR) in Egypt, and possibly other developing countries, can be provided: (1) There is a need for an operational framework with performance targets for integrating risk reduction into urban planning as a tool to guide different stakeholders involved in human settlement development; (2) Urban planners, flood risk experts, and other stakeholders should be brought together to build their capacity and enhance their awareness of the necessity of collaboration and understanding of the data and the methods as the first step for FRR; (3) The economic benefits of communicating flood risk with all stakeholders need to be adopted to motivate officials to fund such projects; (4) The data needed for FRR must be collected, improved, shared, and refined, including data for vulnerability assessment. (5) Building an effective information exchange system on climate change at regional and international levels. (6) Building expert dynamic systems for disseminating information, analyses, and relevant recommendations. (7) Enhancement of capabilities for monitoring, prediction, analysis, and dissemination in the present and future.

Although the analysis is based on a small set of experts, it includes many senior experts with academic and executive positions. A minor limitation was the language barrier between English and Arabic, though a limited amount of translation was required. This study highlighted the relatively weak flood governance in Egypt, as shown by the poor integration between spatial planning and flood risk assessment at all levels. Further studies that dive deeper into the seven suggested solutions, their implementation methods, obstacles, and requirements, are needed. The results can support planners and decision-makers from both disciplines at academic and practical levels to contribute more effectively to building flood-resilient communities. Better understanding each field's perception of the role of the other is a first step in the right direction.

CRediT authorship contribution statement

Aly Esmaiel: Conceptualization, Methodology, Software, Formal analysis, Data curation, Writing – original draft, Writing – review & editing. **Karim I. Abdrabo:** Software, Formal analysis, Data curation, Conceptualization, Methodology, Writing - original draft, Writing - review & editing. **Mohamed Saber:** Supervision. **Richard V. Sliuzas:** Conceptualization, Methodology, Supervision, Project administration, Writing - review & editing. **Funda Atun:** Conceptualization, Methodology, Supervision. **Sameh A. Kantoush:** Supervision, Funding acquisition. **Tetsuya Sumi:** Supervision, Project administration, Funding acquisition.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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