DETERMINATION OF FLOOD RISK MITIGATION MEASURES FOR URBAN AREAS

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Abstract - Floods causes direct and indirect damages to properties and infrastructures as well as having impact on lives and health of the population, commercial market, agricultural areas, cultural heritage, flora and fauna. Such huge variety of its effect makes it difficult to control if not managed with an integrated approach. Thus, determination of flood risk mitigation measures, from different perspectives, is desirable so as to achieve integrated solution. The aim of this paper is to determine and classify flood risk mitigation measures in hierarchical order. The main focus is to cover all type of measures that needs to be performed in order to decrease urban flood risks. The determination and classification of flood risk mitigation measures facilitate the selection of the most effective ones in the relevant area. It will provide a wider perspective of flood risk to the institutions dealing with disaster coordination by incorporating different type of measures.

Keywords - Flood Risk, Flood Management, Risk Mitigation Measures, Urban Flooding.

I. INTRODUCTION

During the last decades, due to unplanned urbanization along with rapid increase in population and climate change, increase in the frequency of floods and its consequences on urbanized areas is inevitable [1], [2], [3], [4]. With its huge variety of impacts such as socio-economic welfare of people, commercial market, agricultural areas, urban infrastructures, fauna, flora and etc. makes it difficult to control in not managed with an integrated approach covering the widest possible set of mitigation measures [5]. Therefore, the objective of this study is to determine flood risk mitigation measures so as to decrease negative consequences of it. Besides, as responsible institutions can change by type of measures, to classify mitigation measures into the most adequate cluster plays an important role to address most suitable solutions for corresponding institutions. To draw practical implementations on flood risk management literature, flood risk mitigation measures were examined in this study. As a result 67 measures were determined to decrease negative consequences of it under 9 clusters which are; environmental, flood control mechanisms, improvement in flood resistance, urban infrastructure capacity, legal, maintenance, planning and institutional, social relief, and structural.
The results obtained in this study will contribute urban flood risk management literature by combining all type of mitigation measures as well as providing wider understanding of flood risk for local and national agencies.

II. LITERATURE REVIEW

Studies related to flood risk mitigation measures were examined within the context of this research and it was found that there are flood risk factors indicating the risk basically and risk mitigation measures addressing the solutions to decrease such risks.

On the basis of flood risk factors, different perspectives make it difficult to achieve a common list of risk parameters. Flood hazard and vulnerability risk factors [6], social vulnerability risk factors [7], variety of factors to create a map to determine flood risk zones [8], factors indicating flood capacity [9], building vulnerability factors [10] and natural and human factors [4] were some of the perspectives adopted by several authors according to their objectives.

To decrease the risk of such factors, different points of view were also used by several authors in terms of flood risk mitigation measures. Three flood control options to mitigate flood risk by considering environmental, social and technical benefits of these options were examined at [11]. Risk mitigation measures were divided into two clusters as structural and non-structural at [12]. In another study, constructing sand dunes, developing evacuation plans, and designing insurance schemes were regarded as three flood mitigation and recovery options at [13].
In order to draw a full picture, flood mitigation measures in the United Kingdom were addressed at [14] with existing measures as well as new suggestions. Structural measures as a whole to mitigate flood risks in agricultural fields were examined at [15]. Identifying effective flood risk reduction measures for potential urban flooding were also identified at [16]. However, most of the studies dealing with measures are limited with a specific region, subject or perspectives. In this study all flood risk mitigation measures were identified for urban areas.

III. FLOOD RISK MITIGATION MEASURES

Literature review has been conducted to determine flood risk factors as well as adequate flood risk mitigation measures from the light of these predetermined factors, so as to suggest practical solutions. In the literature, risk reduction measures were addressed as a factor rather than a specific action to take. In order to grasp whole risk mitigation measures, 2 interviews were performed with

Table 1. Urban flood risk mitigation measures

Cluster	ID	Flood Risk Mitigation Measures
Environmental	E1	Afforestation
	E2	Erosion control activities
	E3	Take care of flora and preserve biodiversity
	E4	Take care of fauna
	E5	Waste management activities for soil pollution risk
	E6	Waste management activities for water pollution risk
	E7	Creation of wetland
	E8	Improvement in soil condition in agricultural lands
Flood control mechanisms	C1	Dam safety activities
	C2	Water storage works
	C3	Flood control mechanism for coastal sides
	C4	Flood diversion activities
	C5	Improvement of flood control structures
	C6	Drainage activities for agricultural lands
	C7	Stream improvement
	C8	Building dam
	C9	Crop protection works
Improvement in flood resistance	R1	Improve flood resistance of industrial buildings
	R2	Improve flood resistance of public infrastructures
	R3	Improve flood resistance of education centres
	R4	Improve flood resistance of healthcare centres
	R5	Improve flood resistance of parks and open spaces
	R6	Improve flood resistance of historical places and cultural heritages
	R7	Improve flood resistance in residential buildings
	R8	Improve flood resistance in commercial buildings
Urban Infrastructure capacity	U1	Increase the capacity of roads
	U2	Increase the capacity of storm water drainage networks
	U3	Increase the capacity of information dissemination systems
	U4	Increase the capacity of electricity systems
	U5	Increase the capacity of natural gas systems
	U6	Increase the capacity of water supply facilities
	U7	Increase the capacity of sewage network
Legal	L1	Improvement of structural material in building code
	L2	Improvement of floor area coefficient
	L3	Improvement of elevation and basement condition in building code
	L4	Improvement of flood resistance in building code
	L5	Improvement of H_{max} limit
	L6	Improvement of total floor area coefficient
	L7	Improvement of the policy enforcement

Table 1. Continued

Maintenance	M1	Maintenance of transportation network
	M2	Maintenance of water supply facilities
	M3	Maintenance of drainage facilities
	M4	Maintenance of dams
	M5	Maintenance of flood control structures
	M6	Scheduled cleaning activities
	M7	Controlling wastes of industrial buildings
Planning and Institutional	I1	Improvement of flood response plan
	I2	Land use planning
	I3	Improve flood and risk modeling
	I4	Early warning developments
	I5	Flood and risk forecasting developments
	I6	Improvement of evacuation routes
	I7	Improvement of slums and informal areas
	I8	Installation of evacuation signs
	I9	Improvement of response team
	I10	Floodplain developments
Public Social relief	P1	Controlling population increase and distribution
	P2	Saving funds for people with low income
	P3	Raising risk awareness level
	P4	Improvement of insurance system
	P5	Development of plan for incapable population
	P6	Community education programmes
	P7	Providing emergency kits and evacuation plans
Structural	S1	Promote people to reinforce their houses
	S2	Flood-proofing actions
	S3	Complement the flood protection of structures such as flood walls
	S4	Urban rebuilding works

"a professional from meteorological institution with 21 year-experience" and "a municipality professional with 15 year-experience" so as to cover all mitigation measures for urban areas from the light of risk factors. As a result, 67 mitigation measures were determined under 9 clusters that could decrease the risk of flooding as shown in Table 1.

A. Environmental Measures

It encompasses the measures such as afforestation, erosion control activities such as terracing, increasing the protection of nature such as fauna and flora as well as controlling contaminations to natural environment which exacerbates the negative consequences of flood. Such measures can be regarded as parameters to decrease the vulnerability of an environment as well as increasing the resilience of urbanized areas [17].Totally 8 measures were determined to decrease the risk of urban flood. Afforestation indicates the increase in the number of trees. It was included because trees can absorb more water leading to decrease in the quantity of runoff. Erosion control activities addresses all making the area safer for the risk of erosion during runoff. Preserving biodiversity is one of the most important environmental concerns, so in order to control the impact of flood on flora; some measures need to be performed such as training special team to take care of flora. Moreover, fauna is another concern related to disasters which have not taken enough attention. Therefore, creating special rescue team for animals or increasing the number and the condition of animal housing will help fauna to deal with flood events. Soil and water pollution control activities were included because soil and water are some of the most crucial resources for human beings. With such control, environmental concerns for contamination can be reduced. Creation of wetland was included as wetlands can act as sponges. And lastly, improvement in soil condition for agricultural land was covered due to the impact of heavy machinery decreasing the rate of infiltration that leads to increasing runoff in agricultural lands.

B. Flood Control Mechanisms

It addresses structural measures that can be performed with hard engineering such as creating flood control structures near dams, storm water detention ponds, storm or tidal surge barriers, construction of levees, dykes or embankments, floodwalls and so on. Totally 9 measures were found having impact on flood loss level. Dam safety activity was included due to the decrease the possibility of dam collapse flooding. Water storage works indicate storage of all type of excessive runoff to decrease the impact of flood. As some cities lay along with the offshore, flood control activities for coastal sides become ubiquitous such as tidal or storm surge barriers. Flood diversion activities cover the effort of diversion of bypass channels or rivers if an area is located in floodplain. Improvement of flood control structure is about the number, condition or location of levees, dykes, embankments and so on. Drainage activities for agricultural land are about the creation of a system for optimum soil water level for the purpose of irrigation. Moreover, stream condition is one of the most important factors having impact on direct runoff, so improvement is a vital measure especially where slope is too little. Building dam measure was included as it can control the riverine flood, however, possibility of the failure of dams should be considered in the design phase. At last, crop protection works includes floodwalls along with crops if necessary. Some of the structural control measures can also be found at [18].

C. Improvement in Flood Resistance

It includes the improvement of valuables in urban areas such as industrial buildings, infrastructures, hospitals, schools, parks, open spaces, historical places, residential and commercial buildings. The main motivation is to increase the durability of such building to flooding. There are 8 measures determined in this cluster. Resistance of industrial building was included because such places address huge risks in terms of contamination, so the resistance of such places needs to be improved. Public infrastructures require a huge amount of cost and effort for public and therefore needs to be improved so as to decrease the damage potential of it. Education centers indicate the future of an area and most of time people who are being educated are more vulnerable than others such as children. This addresses the need of improvement of such places. Healthcare centers or hospitals are one of the most important instruments dealing with response to disasters. The resistance of such places needs to be improved as they must resist during flood events. Parks and open spaces are places in where people meet and make a plan during disastrous events, so such places need to become more resilient to flooding. Resistance of historical places is also important as they are the part of culture of inhabitants. At last, the improvement of residential and commercial buildings is crucial as they are the hearth structures of life indicating the need of living and working.

D. Urban Infrastructure Capacity

It generally encompasses increasing the capacity of roads, storm water drainage networks, warning dissemination system, water supply facility, sewage networks and so on. These improvements will increase the durability of urban areas as well as decreasing the potential future flood risks. In this cluster a number of 7 measures were determined. Increasing the capacity of road mainly indicate the need of adequate accessibility during flood. Increasing the number of secondary road can be a good example for the measure so ac to decrease traffic to access critical places without any trouble. The capacity of storm water drainage networks is a major reason for urban flooding as a result of excessive flow, so there is an enormous impact of such networks capacity on area's durability to flood disaster. Information dissemination system capacity covers, warning dissemination, telecommunication, better use of media and internet. Moreover, the capacity of some of the other systems which are at the hearth of city life such as electricity systems, natural gas distribution systems, water supply facilities and sewage network, need to be improved. Putting electricity system underground, protection of sources of drinking water and conversion of compound sewage to separate sewage can be performed to decrease negative consequences of flood. Besides, such systems can also be regarded as element at risk with their high economic values.

E. Legal

Legal cluster includes those which are related to regulations such as building code improvement in terms of structural material, basement condition or flood resistance. It also covers actions such as to improve the condition of floor area coefficient, total floor area coefficient, maximum height and policy enforcement as well as improvement in legal conditions of floodplain developments. Totally 7 measures were determined within the cluster. Measures related to building code indicate the improvement of legal regulations for structures. Similarly, floor area coefficient, total floor area coefficient and Hmax limit addresses the importance of better protection of building cover; moreover, improvement of floor area coefficient could lead to increase in effective infiltration. However, even though the regulations for flood or any type of disaster is strong, if there is a lack of control in policy enforcement, they do not mean anything. So, in order

to develop some policies to improve the enforcement of policy this measure was included in this study.

F. Maintenance

Building or creating hard structural measures is not enough to propose a solution to flood problems in urban areas. Structures or facilities such as dams, flood control structures, roads, industrial places and water treatment facilities need to be maintained. Scheduled cleaning can decrease the blockages of flood water as well, especially cleaning close to deciduous trees in the autumn. It will increase the coping capacity of an area over pluvial floods [19]. The cluster consists of 7 measures totally. It encompasses maintenance and scheduled monitoring of roads, railways, bus stops etc. of high risk zones, maintenance of drainage lines in order to prevent surprise blockages during flooding, maintenance of dams so as to decrease the risk of dam failure flood, when water flow is extreme over a dam. Moreover, maintenance of floodwalls, embankments or levees plays a crucial role to protect preferred place. At last, scheduled controlling of industrial or any other sort of buildings that emit hazardous or chemical wastes was coverd within this cluster as when flood water touches hazardous chemical, they threaten the health of a society via direct touch or fresh water supplies.

G. Planning and Institutional

Planning and institutional cluster covers all the measures which are related to capacity of institutions dealing with flood risk reduction such as state hydraulic works, local municipalities or disaster coordination centers such as flood response plan improvement, land use planning, flood risk mapping, early warning developments, evacuation routes, controlling buildings without permissions and so on [20]. So as to initiate these measures, there is an urgent need for determination of responsibilities country by country. This cluster consists of 10 measures. Improvement of flood response plan indicates the need of plan, emergency response team, first aid stock and detailing the chain of order. Land use planning is about the consideration of imperviousness, zoning, decision to build fewer houses and so on. Measures related to early warning, risk modeling and forecasting covers different type of mapping such as vulnerability, hazard or risk maps, improvement of meteorological observation stations to gather more data to forecast flood events, increasing the number and condition of river height gauging stations and so on. As evacuation during flood is one of the most critical measures to save life, improvement of evacuation routes and installation of evacuation signs and improvement of response team such as flood boat trainings were involved in this study. Furthermore, floodplain developments such as prevention of new settlements in floodplain or relocating, and improvement of slums and informal areas in order to control buildings having no permission were determined as such buildings and its occupants are more vulnerable than others.

H. Social Relief

There are some measures that is about the relief of public living in the region of flood risk especially for people with low income or with incapability. Controlling population increase, saving funds for people with low income, raising risk awareness level, creating special rescue team for incapable or old population, providing emergency kits for especially low-income people will help the community to cope with flood disaster easier [9]. This cluster consists of 7 measures at all. Controlling population increase indicates the reduction of vulnerable population as well as the negative impact of dense populated regions. Saving funds, providing emergency kits for people with low income and development of policies and plans for incapable population such as children, elderly, migrants or new residents measures aim to decrease individual vulnerability. Besides, improvement in insurance system is one of the most vital measures to decrease flood risk as insurance companies are one of the most important stakeholder to deal with disaster. Raising risk awareness level along with community education programs to help people to perceive flood risk can also be seen as one of the most effective non-structural measures that worth carrying out.

I. Structural

Structural measures includes promoting people to reinforce their houses especially those who live in informal places, flood proofing actions, complement the flood protection of structures such as flood walls and rebuilding works. 4 mitigation measures were determined under the layer of structural cluster. Main reason to hold these measures is to increase the durability of structures over flooding. Promoting people to reinforce their houses indicates decreasing the risk of future floods as well as increase the durability of a buildings' current condition. Flood-proofing measures especially related to covering indicate the protection of fragile materials, objects, belongings or values by obstructing the touch of water. Some structural measures such as flood walls could directly decrease the risk of single houses especially in floodplains where the probability of riverine flood is high. At last, buildings, structures, infrastructure facilities and so on become old, then there is a need of reconstruction phase for the region to decrease possible flood risks.

CONCLUSION

This study was an attempt to determine all type of flood risk mitigation measures that can be performed by one of the responsible institutions such as disaster coordination center, water and sewerage services, state hydraulic works, local or national authorities so as to decrease possible negative consequences of urban floods. In this respect literature review was performed to determine risk mitigation measures for urban areas. Then two interviews were conducted in order to grasp whole concept of urban flood as well as not to miss any type of measures. The results show that there are a huge variety of mitigation measures. Moreover, the effort that needs to be spent can change enormously from measure to measure. For future studies, more detail determination of mitigation measures can be achieved followed by a responsibility assignment for each of them to the responsible institutions.

ACKNOWLEDGEMENT

The work described in this paper was supported by Coordinatorship of Scientific Research Projects of Yıldız Technical University (Project Number: FYL-2017-3208).

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