A Methodological Framework for Operationalization of Flood Risk Management

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Abstract. Flood risk management has undergone significant transformations during the recent past. Climate change is very likely to bring a higher probability of extreme weather events. Climate change is a significant challenge for urban growth in coastal delta cities. Transformation of floodplains for urban development is a vital component of flood exposure, and changes in this component can lead to variations in flood risk. Socio ecological system conceptualizations suggest that resilience is the key to managing complex systems and to reduce vulnerability which is a result from the inherent uncertainty of flood risk. Theoretical understanding of flood risk management has advanced over the years but it is still seen that there are shortcomings in the operationalization concepts and methods. One of the main reason is lack of a common framework for clear recognition and understanding of the components of flood risk management for all stakeholders. Therefore, this research has questioned the current status of flood risk management and provide recommendations for operationalization. The Analytic Hierarchy Process (AHP) is a multi-criteria analysis technique that can be applied for structuring of complex decision-making problems involving multiple stakeholders, and scenarios. Therefore, this paper has developed a solution model for structuring the complexity of flood risk management and increase the certainty of the objectives of stakeholders. Result of the study has highlighted the main criteria and the sub criteria to structure the complexity of the planning process for operationalization of flood risk management.

1 Introduction
The continuing increase of flood risk around the world is contesting the decision making process of the traditional flood risk management systems [1-2]. The narrow characterization of flood risk often fails to take the complex and socio spatial and temporal dynamic nature of the flood risk into account [3-6]. The concept of socio-ecological resilience highlights that, the vulnerability of the social system has been considered as the central aspect of decision making process which determines if the hazard would be converted into a disaster [7-13]. Absolute flood prevention is unattainable and water and land use are inseparably connected with each other [7] [14]. Therefore, the external pressures or changes of either water or the land uses result in chains of impacts on both the systems. Therefore, the importance of considering of complex interdependencies of flood risk including the nonlinear interactions among land and water has been recognized [15-18]. Flood Risk Management (FRM) measures are required to be designed based on the scenario approach [19]. Diversification of FRM measures and
application of an environmentally friendly concept such as living with water can be taken as examples[20-24]. However, it has been recognized that, characterization, assessment, and evaluation of flood risk is a difficult task because dynamics and uncertainties of the natural and social systems[25-26]. It has been recognized the need of systems-based characterization of flood risk. Further it concludes that the assessment and management require a shared understanding of flood risk with the stakeholders. Planning process of FRM is a complex process which involves multiple stakeholders each with their own objectives. Therefore, the planning process is a challenging task to provide certainty and reduce flood risk[27].

Flood risk however cannot be solved by any single organization. This is Because, a solution for one group of stakeholders often creates new problem for another[17]. Implementation of FRM measures particularly, at the local level, faces strong resist from the local communities[28]. Divergent stakeholders involve in the planning process due to the multi-dimensional nature of flood risk[29-30][17]. The objectives of the FRM highlights the integration between land and water[31-32]. These objectives are not meant to be isolated and should be considered in order to gain a broader socio-economic development[33-36]. Therefore, FRM has highlighted the importance of integrated objectives which involve multiple stakeholders across sectors and levels of decision making[37]. This transformation has challenged the established governance boundaries particularly, between institutions related with land and water. The flood risk management strategies are required to be evaluated based on the impacts on economy, society, and environment in long term. Thus, FRM strategies are also able to lower the risk of flooding to an acceptable level for whole society. Therefore, the effectiveness of flood risk management measures is determined with reference to the achievement of the objectives of the local communities considering the geographical, and cultural context[38].

Operationalization of the FRM depends considerably on the stakeholders’ knowledge system. Stakeholders define the spatial quality of the floodplain considering the objectives of different communities, climatic scenarios, available resources, methods, tools, institutions, and the flexibility of the planning process[30]. Therefore, the integration of stakeholders’ knowledge systems, social learning, and exploration of opportunities to increase the adaptive capacities are underlined as the central methodological concern of the planning process for the operationalization of food risk management[39]. Practicing of flood risk management requires new governance arrangements for collaboration of multiple stakeholders, new methods for power and resources sharing[37][40-41]. As a result, operationalization of flood risk management is a governance context-dependent phenomenon[36][38][42-45]. Operationalization of Flood risk management requires a common decision-making framework to optimize the objectives of all stakeholders. Therefore, decision makers are increasingly questioning the way of applying spatial planning for flood risk management[46].

Planning process of FRM is composed how information of flood risk is socially collected, analyzed communicated, and evaluated[47]. There are many obstacles for operationalization of flood risk management with spatial planning[48]. In the past, the role of spatial planning was often narrowed down within flood risk management and considered as a regulatory instrument[30]. In the present context, spatial planning has been considered as a collaborative decision-making process to balance and integrate spatial claims of diverse stakeholders such as for water retention and residential development to achieve spatial quality[35][49]. However, we are yet far from putting integration into practice[48][50]. Plural understanding of stakeholders particularly engineers and the spatial planners, on the interdependencies between land and water has become one of the key challenges for the operationalization of flood risk management[51-53]. In addition, there is relatively autonomous position of water authorities and civil engineers are very often dominated the decision making process[54]. Fragmentation of governance structure is a barrier in the practice of adaptive management strategies[55]. Further, poor legal certainty in the planning system is also opposed the practice of the FRM measures. Flexibility of the governance system, as well as the perceptions of the stakeholders, and are important aspects for defining the adaptive management measures in the planning process[56-57].
There are no common frameworks to structure complexity of planning process and to evaluation criteria of the priorities of stakeholders considering the socio spatial and temporal dynamics of flood risk[58-59]. Research has been largely ignored define frameworks to operationalize FRM as part of the spatial planning and development[60]. The common question is how to share the costs and benefits of FRM measures among the stakeholders and how to share the responsibilities of adaptions to flood risk[61]. The assessment process is required to balance the impacts of alternative flood management solutions among multiple stakeholders under future deep uncertainty[62]. FRM strategies are required to be evaluated based on cost, risk reduction, economic impacts, social and environmental impacts in long term.

Stakeholders’ knowledge of the dominant feedback loops, how they cause flood vulnerability, how they interact across different socio, spatial and temporal scales is compulsory to evaluate the FRM measures[17][63]. These models are required to explore a wider range of possible future scenarios[15][64]. The assessment and the evaluation of flood risk and defining acceptable limits of management measures should be a continuous and integrated process. However, methods to analyze and quantify environmental as socio economic changes related to flood risk, both in space and time are not yet common[65]. The effectiveness of flood risk management measures is determined with reference to the achievement of the objectives of the local communities considering the geographical, and cultural context[38]. There is a lack of research to demonstrate that the how spatial planning can be successfully achieve flood risk management[66-67]. Multi-criteria decision support models in the Planning process of flood risk management system are required to evaluate and trade-off the multiple objectives of stakeholders. Therefore, multi-criteria decision-making tools such as Analytical hierarchical process (AHP) are important to handle quantitative and formulate stakeholders conflicting objectives in the planning processes, Operationalization of the flood risk management is based on the stakeholders’ knowledge system which is defined as the spatial quality of the floodplain community at different scenarios and available resources, methods, tools, institutions, and the flexibility of the planning process[30]. Therefore, the integration of stakeholders’ knowledge systems and exploration of opportunities for social learning are underlined as the central methodological concern of the planning process for the operationalization of flood risk management [39]. Practicing of flood risk management requires new governance arrangements for collaboration of multiple stakeholders, new methods for power and resources sharing and hence practical guidelines [37][40-41]. As a result, operationalization of flood risk management is a governance context-dependent phenomenon [36][38][42-45]. Operationalization of Flood risk management requires a common decision-making framework to optimize the objectives of all stakeholders. Therefore, decision makers are increasingly questioning the way of applying spatial planning for flood risk management[46].

Practicing of FRM can be defined as how information of flood risk is collected, and socially analyzed communicated, evaluated, and application of adaptive decisions[47]. There are many obstacles for operationalization of flood risk management with spatial planning[48]. In the past, spatial planning was often narrowed down within flood risk management as a regulatory instrument[30]. However, in the present day, spatial planning has been considered as a collaborative decision-making process to balance and integrate spatial claims of diverse stakeholders such as for water retention and residential development to achieve spatial quality[35][49]. However, we are yet far from putting integration into practice[48][50]. Plural understanding of stakeholders on the interdependencies between land and water has become one of the key challenges for the operationalization of flood risk management[51-53]. In addition, there is relatively autonomous position of water authorities and civil engineers are very often dominated the decision making process[54]. Further, poor legal certainty in the planning system is also opposes the practice of the flood risk management measures. Fragmentation of governance structure is a barrier in the practice of adaptive management strategies[55]. Flexibility of the governance system, as well as the perceptions of the stakeholders, and are important aspects for defining the adaptive management measures in the planning process[56-57].
2 Research objectives
There are no common frameworks to structure the complex planning process and to evaluation criteria of the diverged priorities of stakeholders considering the socio spatial and temporal dynamics of flood risk[58-59]. Research has been largely ignored define frameworks to operationalize FRM as part of the spatial planning and development[60]. The common question is how to share the costs and benefits of flood risk management measures among the stakeholders and how to share the responsibilities due to adaption to flood risk[61]. Therefore, the assessment process is required to balance the impacts of alternative flood management solutions among multiple stakeholders under future deep uncertainty[62]. Therefore, it is required to understand the economic returns of various flood management options to lower the risk of the total portfolio considering the long term flood impacts. Therefore, dynamic models which describes human-flood interactions are necessary for assessment of flood risk[15]. Stakeholders’ knowledge of the dominant feedback loops, how they cause flood vulnerability, how they interact across different socio, spatial and temporal scales is compulsory to define flood risk management measures to lead flood resilience[17][63]. These models are required to explore a wider range of possible future scenarios[15][64]. However, methods to analyze and quantify environmental as socio economic changes related to flood risk, both in space and time are not yet common[65][66]. Therefore, the assessment and the evaluation of flood risk and defining acceptable limits of management measures should be a continuous and integrated process. There is a lack of research to demonstrate that how spatial planning can be successfully achieve flood risk management[66-67]. Multi-criteria decision support models in the Planning process of flood risk management system are required to evaluate and trade-off the multiple objectives of stakeholders. Therefore, multi-criteria decision-making tools such as Analytical hierarchical process (AHP) are important to handle quantitative and formulate stakeholders conflicting objectives and manage the complexity of planning processes.

3 Research methodology
Frameworks of decision making are “cognitive representations of the problem situation by stakeholders”. Frameworks provide a logical, analytical base to explore, structure, assess and manage the problem conditions.

3.1 Development of decision making framework & Determine the relative weights of criteria and sub criteria
Multi-Criteria Decision Making is a technique which has been successfully applied for the optimization of and allocation of water resources among conflicting stakeholders[69]. The Analytic Hierarchy Process (AHP) is a multi-criteria analysis technique that can be applied to manage complex decision-making process which includes multiple objectives of multiple stakeholders with multiple scenarios[70]. Literature survey and Delphi technique have been conducted for the identification of criteria and sub-criteria of the decision making framework to operationalize flood risk management. The experts have been selected considering the their educational and the professional qualifications. AHP has been applied to structure the decision-making process into a hierarchy framework. AHP technique has been used to calculate priority weight of criteria and sub criteria. It has been developed decision matrix based on pairwise comparisons according to the experts’ judgments. Delphi technique has been used to collect these professionals’ judgement of the relative importance of the criteria and the sub-criteria. Perception survey on ranking the criteria and the sub-criteria of the framework has been conducted until the results are stable. Pairwise comparisons between each set of criteria on the level below are made with respect to the criteria in the next highest level. Pairwise comparisons involve selecting criteria and sub-criteria centering on which item is more important with respect to the attribute, and further, stating how much more important the criteria are over the other criteria. The consistency test has been conducted to check the validation of judgments made by the experts in the process of ranking.
4 Discussion & Conclusion

4.1 Main criteria of the framework
Result of the study has highlighted that the main criteria to structure the complexity of the planning process and sub criteria which are required evaluate the criteria. As highlight in the figure 1, the main criteria of the framework for operationalization of flood risk management are (1) conceptualization (2) assessment of the planning process (3) the discourse of the stakeholders in the governance context as well as the (4) available interaction mechanism of stakeholders for participatory decision making. Conceptualization describes the Planning process of flood risk management system includes integrated and adaptive objectives, strategies, guidelines, and lead to sustainable development of the community. This definition is carried out because the stakeholders of the system characterize and assess the flood risk following the non-linear interactions of flood risk. Accordingly, the assessment of flood risk, and the evaluation of alternative management measures are based on the multiple objectives of these stakeholders at multiple scales as well as multiple scenarios, focusing mainly on long-term social wellbeing. Therefore, Conceptualization of planning process means that the stakeholders consider the Flood Risk Management to be a continuous, integrated, socially analyzed, and evaluated process to manage the uncertainty.

Assessment of the planning process means the understanding of the uncontrollable nature of flood occurrence. Therefore, the role of the planning process is the identification of flood risk management measures to increase the adaptive capacities of the social system to manage the uncertainty. Increasing the adaptive capacity of these social systems can thereby involve effectively in the face of diverse scenarios of flood risk. This is done by creating a synergy between multiple objectives of multiple stakeholders at different scales, while considering the integration of the knowledge and the interactions of stakeholders. The discourse of the stakeholders describes the policy principles of the knowledge system of the stakeholders. Stakeholders have recognized the significance of integrated and adaptive goals & strategies for FRM as well as the consideration of the social & spatial independence of flood risk for the long-term wellbeing of the society. Therefore, the Knowledge system of the stakeholders has been recognized to be of utmost importance in the participatory decision-making & implementation process in the operationalization of flood risk management. Governance mechanism means the availability of an integrated interaction mechanism among stakeholders to share Power & resources for collaborative decision making, and implementation of flood risk management goals, strategies, and guidelines. Governance of the system has recognized and facilitated the legitimacy of the participation of stakeholders in the decision-making & the practice of flood risk management. The criteria weight of each of the above four criteria to practicing of flood risk management are as 0.1711, 0.5211, 0.055 and 0.2524 respectively.

4.2 Sub criteria of the framework
There are four sub-criteria which are required to evaluate the conceptualization of planning process of flood risk management are as (a) Flood risk is considered as a complex phenomenon. There are interdependencies between social, hydrological, ecological, etc subsystems. Therefore, FRM includes multiple stakeholders from the multiple sectors. (b) Flood risk management is influenced by multiple factors at diverse spatial scales. Scale sensitivity of flood risk and therefore, importance of assessing/manage flood risk at a different scale. Therefore, analysis and management of flood risk require based on the scales. (c) There are inherent uncertainties in the flood risk management decision-making process due diverse stakeholders with multiple knowledge and interpretations of flood risk management are involved in the process of decision making. Therefore, planning process is to be a continuous and based on social learning process. (d) Decision making process of Flood risk management has required the integration of the multiple objectives of all stakeholders. The importance of these sub-criteria for conceptualization of flood risk management are as 0.1192, 0.0540, 0.2735 and 0.5526 respectively.
Sub criteria to evaluate the assessment process of planning process are as (a) Identification of the potential strategies to increase the adaptive capacities to maintain the ecological functions of the floodplains with different climatic scenarios rather than design strategies of flood control measures based on probability thresholds of flood events. (b) Identification of diverse flood management measures including measures to increase resistance capacity, recovering capacity, the transformative capacity to manage the uncertainty of flood risk of different scenarios) to manage flood vulnerability with different climatic scenarios. (c) Identification of the potentials flood management strategies for Maintenance of Hydrological integration over the watershed/ spatial integration to management uncertainties of different climatic scenarios. (d) Identification of the potentials flood management strategies to increase social integration / multifunctional land uses over floodplains by identifying a common acceptable thresholds integrating the diverse spatial claims of stakeholders/ social integration (trade-offs of multiple social interactions of flood risk) to cope up with different climatic scenarios. The relative importance of these sub criteria are as 0.572, 0.256, 0.115, and 0.057 respectively.

Sub criteria which required to characterize Knowledge system of stakeholders are as (a) Identification of the potential strategies to increase the adaptive capacities to maintain the ecological functions of the floodplains with different climatic scenarios rather than design strategies of flood control measures based on probability thresholds of flood events. (b) Identification of diverse flood management measures (including measures to increase resistance capacity, recovering capacity, the transformative capacity to manage the uncertainty of flood risk of different scenarios) to manage flood vulnerability with different climatic scenarios. (c) Identification of the potentials flood management strategies for Maintenance of Hydrological integration over the watershed/ spatial integration to management uncertainties of different climatic scenarios. (d) Identification of the potentials flood management strategies to increase social integration / multifunctional land uses over floodplains by identifying a common acceptable thresholds integrating the diverse spatial claims of stakeholders/ social integration (trade-offs of multiple social interactions of flood risk) to cope up with different climatic scenarios. The relative importance of these sub-criteria are as 0.567, 0.076, 0.204, 0.153 respectively.

Participatory mechanism or governance tools to power & resource distribution patterns among stakeholders of the governance systems is characterized through the following sub criteria which are (a) Mechanisms available for Integration among the land & water institutions at all scales and levels (b) Mechanisms available for Integrated goal setting & catchment wide approach for decision making (c) Mechanism available for Multiple Regime Governance Traditions (top-down + bottom-up) and (d) Mechanism available / Legitimized tool availability for Empowering local stakeholders in decision making & implementation of FRM system (spatial planning). The relative importance of these sub criteria are 0.3937, 0.1375, 0.0753 and 0.3937 respectively. The developed framework demonstrates how to structure the planning process and governance context to achieve flood risk management. Therefore, this framework can be used to assess the level of adaptive capacity of the planning process of a given context and it has provided the recommendations to improve flood resilience of that context. Developed framework is sensitive to the governance context. Therefore, more case studies at various governance context are needed to further strengthen operationalization of flood risk management.

![Figure 1. A framework to operationalize flood risk management](image-url)
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