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Flood Resilience Index - Methodology And Application

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FOOD RESILIENCE INDEX – METHODOLOGY AND IMPLEMENTATION

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In recent years the number of people affected by flooding processes increases up to the point where the organizational structure of urban communities threatens to experience the significant direct and indirect damages. The vulnerability to flooding processes due to sophisticated assets is high and the assessment of flood resilience becomes the main direction to follow within integrated flood risk management.
This paper takes a first step in bringing resilience in integrated flood risk management through a framework that is employing five dimensions in order to evaluate the level of disturbance and ability to preserve and function during and after the flooding on one side and connected with the flood risk management cycle on the other side. The method recognizes different scales and functions within the urban system. The application is done on city of Nice taking into account existing flooding processes, economic, social and institutional characteristics.

INTRODUCTION

The shift from traditional flood risk management put a vulnerability of community in the focus. The new approach deploys a set of measures that bring changes in social and economic drivers in urban systems as well as improved risk management. The way forward is leading to resilience, having in mind all challenges that are obstructing implementation of this new approach. Based on this view, the shift is done from typical technical solutions that is provided by pure engineering science to a concept of understanding the conditions associated with human actions, economic change and institutional capacity. The methodology presented in this paper is done within CORFU project. The Collaborative Research of Flood Resilience in Urban Areas project (CORFU project) is a part of the Seventh Framework Programme (FP7) of the European Union. The project looks at advanced and novel strategies to provide adequate measures for improving flood management and flood resilience in cities.

RESILIENCE AND VULNERABILITY

Urban development and increase of vulnerability move forward urban communities towards a risk culture and development of ability to accept a certain level of flooding. The ability to accept and be able to reorganize introduces a new concept, resilience. Level of acceptance of flooding with certain damage is expressed through carrying capacity.
Assessing the flood risk in urban systems brings three concepts: carrying capacity, vulnerability and resilience [1]. The concept of carrying capacity identifies the maximum tolerable damage

that a community or a city could bear. The concepts of vulnerability and resilience serve to measure and to assess the carrying capacity of a community or a city. The vulnerability expresses the impact of disturbance of a system; the resilience is to describe the capacity of a system to absorb the shock.

Vulnerability

There is a need to tell the difference between vulnerability and resilience. Vulnerability presents a pre-event characteristic of a social system that has a potential to harm. Vulnerability is in a function of exposure or sensitivity of a system to disturbance. This is explained through answer on the question who or what is at risk? Vulnerability is defined as the conditions determined with physical, social, economic, or environmental factors or processes which are increasing the weakness of community to the impact of hazard [2].

Adding resilience to flood risk management

The resilient urban systems and urban communities have ability to accept, resist, recover and learn from the events. Capacity of urban systems and communities is improved in each part of the flood risk management cycle. It covers actions related to preparedness, response and recovery. Within this research the five elements of flood risk management are developed: relief, resist, response, recovery and reflect.

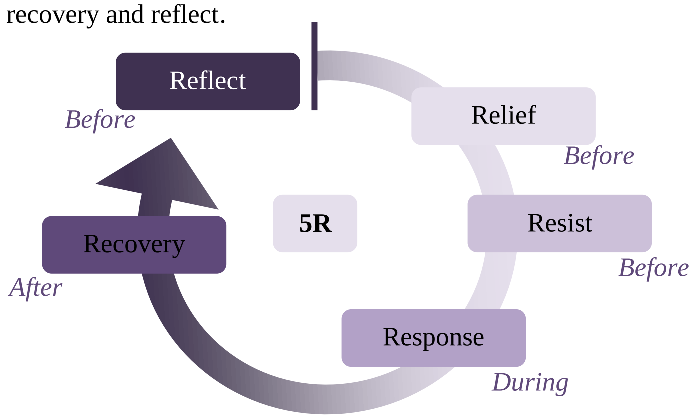


Figure 1: Elements for flood risk management cycle – CORFU project

- Relief – A buffer element. The use of existing structures and urban functions for collection of flood water (green areas, different playgrounds...) is dominant. Measures implemented before a flood. Implementation of physical, technical, non-structural and procedural measures relates to the concept “living with floods”, such as wet flood proofing.
- Resist – Prevention of flood risk if possible, threshold capacity; measures implemented before a flood. Limiting flood damage and easy recovery by planning and adapting buildings, infrastructure, surfaces and economic activity relate to the concept of resistance

- Response – Measures taken during the flood. Actions that focus on crisis management. Flood impact is reduced by implementation of physical, technical, non-structural and procedural measures relates to the concept “living with floods”.
- Recovery – Providing support to recovery processes and engaging and building capacity in communities enable to cope with the impacts after flooding events.
- Reflect – Actions focus on increasing awareness and adaptive capacity, learning from past event and/or preparation for an uncertain future. Enhancing the awareness and engagement in all aspects of flood risk and the means of managing it at the policy level (politicians/decision makers), professionals (of the involved authorities and elsewhere) and at the public participation (people, companies, developers, insurance companies).

Actions and measures are directly connected with flood resilience. They are related to strong intent to increase capacity building of human resources, better land use management, increased flood preparedness and emergency measures that are taken during and after a flood event.

METHODOLOGY AND IMPLEMENTATION

The new methodology of urban diagnostic is facing an urban flood risk issues. The approach is based on the development of urban flood resilience with indicators able to provide a comprehensive overview of vulnerability and resilience of a city and community. For that reason the different spatial scales for analysis are recognized and physical and social components of urban system.

There are two main players, built environment and social community. The systemic approach is to analyze the urban environment as a complex system.

As stated, flood risk is not only a threat to the city and its inhabitants; it is also one of the essential components of urban structure. The development of methodology and analysis of urban systems through different scales and components can provide essential information for the transformation of the urban spatial organization [3].

The relationship between the nature of interaction and the structure of an urban system is fundamental. City systems - urban systems are very complex. Their function is providing different services for the residents [3]. Four scales are defined for urban system: city, district, block and parcel scale. Mapping of urban system is done with nine defined urban functions (housing, education, safety and governance, health, working, food, leisure and tourism, religion and cemetery) and five city services (water, energy, communication, transportation, waste management) [3]. This is done in order to define the main elements in the urban system.

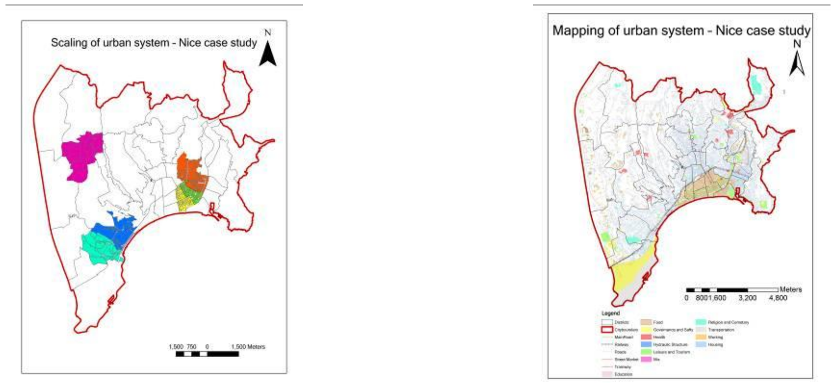


Figure 2: Nice case study scaled and mapped urban system

Flood Resilience Index

Evaluation urban flood resilience is done through flood resilience index (FRI). The index is represented as a level of flood resilience assessment in analyzing area and for certain flood characteristics. In addition, the resilience is an ability to accept a disturbance up to some level. This ability is defined up to the level where the system is able to organize itself and preserve the structure and function. Reflected in urban systems this means that resilience is defined up to the level that urban structure and urban community are able to accept disturbance, preserve the 'level of functioning', organize and recover from it.

Critical assumptions

The presented method is a simplification of reality. The method is addressing the flooding processes in urban systems. The focus is on specified resilience, the flood resilience at the city scale. Interconnection between natural, physical, economic, social and institutional system exist and their separation is arbitrary.

Evaluation of urban flood resilience

A majority of assessment techniques is based on quantitative analysis. The urban system is considered through five dimensions: natural, physical, economical, social and institutional. Within each dimension the set of major indicators is chosen. The set of indicators or variables is taken as a substitute because it is very difficult to quantify resilience in relative terms. The indicators are chosen according to the following criteria: Sensitivity, Availability, Affordability and Relevance.

The methodology is set to take into account different spatial scales. The evaluation of the Flood Resilience Index (FRI) on parcel/building and the block scale focuses on urban function. The evaluation of FRI for the city and district/block scale is done through five dimensions: natural, physical, social, economic and institutional.

FRI on parcel/building scale

The evaluation of the flood resilience index for the parcel or building scale focuses on the urban functions with its requirements (table 2). The set of requirements can be divided to one necessary for a building as a construction and requirements in respect of different function of the building (school, hospital, administrative, police, etc.). Setting the requirements for urban functions is done in respect to flooding processes. Different levels of functioning during and after flooding processes indicate a different level of flood resilience. Setting up an availability level with respect to different flooding conditions there are sufficient data to measure flood resilience for urban function.

Availability levels are marked from value 0 where the requirement is not provided, with value 5 where the requirement is fully provided (table 1). The flood resilience is respectively: very low, low, medium and high for a building.

Table 1: Availability levels of urban functions

Availability level	Description
0	Not available
1	Poor availability – major interruptions
2	Low availability – interruptions provide minimum availability
3	Medium – small interruptions that are tolerable for small flood durations
4	Medium-high – interruptions that are tolerable for long flood durations
5	Requirement fully provided

Table 2: Evaluation of FRI for building scale

Requirements for urban function	Availability level (0 – 5)	Weights (1-5)
EXTERNAL SERVICES		
Energy	0,1,2,3,4,5	1,2,3,4,5
Water	0,1,2,3,4,5	1,2,3,4,5
Waste	0,1,2,3,4,5	1,2,3,4,5
Communication	0,1,2,3,4,5	1,2,3,4,5
Transport	0,1,2,3,4,5	1,2,3,4,5
INTERNAL SERVICES		
Food availability	0,1,2,3,4,5	1,2,3,4,5
Occupation of urban function	0,1,2,3,4,5	1,2,3,4,5
Access to the urban function	0,1,2,3,4,5	1,2,3,4,5
FRI (parcel/building scale)		
$FRI_{building} = \frac{\sum_{i=0}^{5} r_e \times w_i + \sum_{i=0}^{3} r_i \times w_i}{\sum_{1}^{8} w_i}$		

The evaluation of FRI for Nice case study parcel scale is presented in the table below with evaluating critical requirements for Nice case study (old city area) on parcel scale. The 100 year event is chosen with a flooding depth of 20 cm.

Table 3: FRI evaluation of Nice case study (old city area) for parcel scale - residential building

Critical requirement		Description	r_e, r_i	w_i
EXTERNAL DEPENDENCES	Energy	Electric network is water-proof and the fuse box is found above a flood depth. Just minor interruptions could be	4	3

	Water	expected. No, no-return valve for waste water. A drinking water provision might be interrupted. Sewerage system is separated.	3	3
	Waste	Almost no waste collection can be supported during flooding. Garbage trucks cannot access the premises.	2	3
	Communication	Internet services might be interrupted. Mobile phone reception remains operable.	4	4
	Transport	There is one road connecting the building but it is blocked by a flood depth of around 20 cm. If passed, connection to rail, car, and bus transportation is available in all directions but with a delay.	3	4
INTERNAL DEPENDENCEs	Food	The building has possibility for food storage, but it does not provide room for long durations of flooding.	3	2
	Occupation	The property is a residential. It does not have special flood proof features, making it easy for water to flow into the building, thus hindering its level of occupancy greatly.	2	4
	access	There is street connecting the buildings to the city and it is blocked by a flood depth of around 20 cm. The building might be access through the water sheet with a motorized vehicle or by walking provided low water velocity.	2	4
		FRI	2,85	

FRI for block scale

Evaluation of FRI for block scale focuses on both urban functions and city services and flood impact on them. The block is defined as a set of buildings or parcels surrounded by streets. The procedure is set up to recognize the dominant urban function for block scale. Figure 5 represents the example of calculating FRI for Nice case study for block scale.

FRI for city/district scale

Analysis of the whole urban system takes into account beside the built environment the social, economic and institutional dimensions. The five dimensions are defining the urban system: natural, physical, economical, social and institutional. This is done after reassessment of FRI after implementation of the measure. Each dimension contributes to the evaluation of the flood resilience index for the particular urban system. Dimensions are composed with different variables. The approach brings resilience into flood risk management through 5R concept.

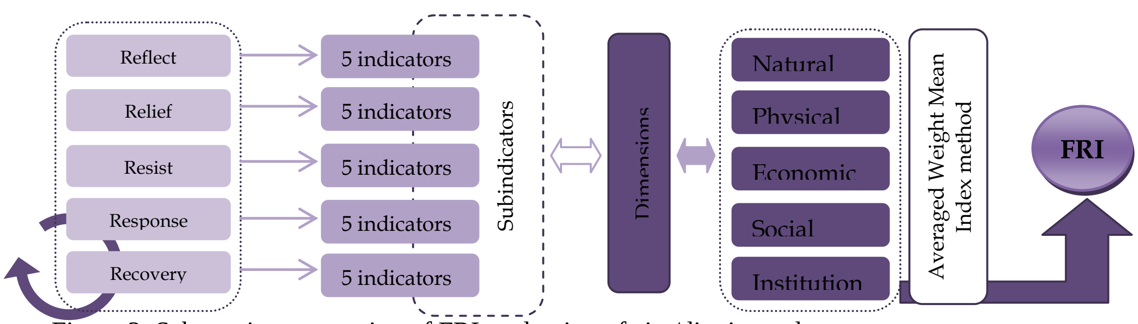


Figure 3: Schematic presentation of FRI evaluation of city/district scale

- **Natural dimension** – describes the space where urban area is located.
- **Physical dimension** – describes and build environment along with existing structural measures
- **Economic dimension** – Increase of households in line with population growth rates and employment rate as a direct link to economic and urban growth
- **Social dimension** – evaluate available resources, health status, knowledge and flexibility as well as connections within the community.
- **Institutional dimension** – Existence of flood management plans, policies, regulations, evacuation plans.

The questionnaire is created in order to describe all dimensions of system. The dimensions are evaluated using The Aggregate Weighted Mean Index or AWMI (for each dimension) [4]. Resulting values for the index have ranges described in table 4.

Table 4: Scales for Flood Resilience Index

Very low 0-2	The activities are not clear and coherent in an overall flood risk management (5R). Awareness is very low on the issues and motivation to address them. Interventions have a short-term character. Actions limited to crisis response.
Low 2-3	Awareness of the issues and motivation to address them exist. Capacity building of human resources remains limited. Capacity to act is improved and substantial. Interventions are more numerous and long-term. Development and implementation of solutions.
Medium 3-4	Integration and implementation of solutions is higher. Interventions are extensive, covering all main aspects of the 'problem', and they are linked within a coherent long-term strategy.
High 4-5	A ''culture of safety'' exists among all stakeholders, where the resilience concept is embedded in all relevant policies, planning, practice, attitudes and behaviour.

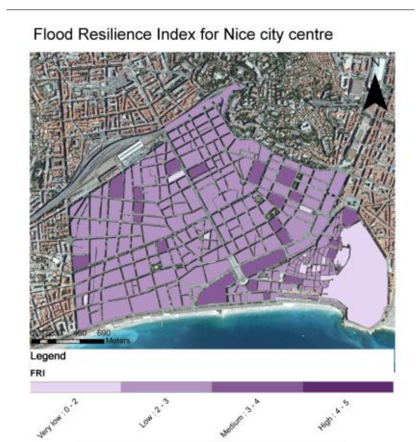
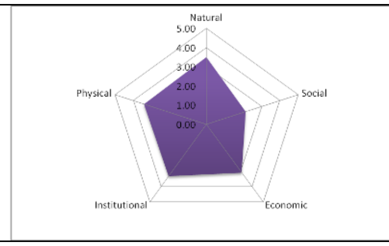


Figure 4: Nice case study - FRI evaluation block scale

Evaluation of FRI for city scale is done following up described procedure on figure 3. After assigning the availability values to each indicator with their respective weights, the overall FRI was calculated and the result of 3,1 was obtained for the current conditions which corresponds to medium flood resilience (table 3). Table 4 below provides an overview of the FRI for each dimension and overall FRI.

Table 5: Overall FRI for the city scale of Nice

	∑wi	∑(xi*wi)	Dimension index ∑((xi*wi)/∑wi)	FRI
Natural	10	35.00	3,50	
Social	28	60	2,14	
Economic	37	115	3,11	**3,1**
Institutional	66	220	3,30	
Physical	97	330	3,40	



CONCLUSION LIMITATIONS OF THE PROPOSED INDEX

The flood resilience concept brings a new philosophy to urban systems, 'living with floods'. The approach transforms the existing structure of urban system and creates a system that is accepting the water with minimal damages, system that is able to recover in a minimum time frame and a system that is able to have a certain level of functioning during the flood.

In this study developed flood resilience index has ability to objectively assess all indicators. The outcome indicators were developed from actions in flood risk management cycle. The flood resilience index still depends on some assumptions. The proposed measurement of indicators relies on weights (assign for each indicator). Some limitations related to providing a quality measure of the process are possible since weights are used to intensify the scores in the assessment.

Acknowledgments

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