A Functional Resonance Analysis Method to risk analysis of functional flood defenses in Yangon

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Abstract

Multifunctional use of flood defences is seen as a promising solution for improving the synergy between flood protection and urban development combining the functions can, however, create unintended dependencies, which can influence the desired performance of the system in unexpected ways. Recognizing the risks associated with these dependencies early during the conceptual design phase can help to improve the system capability to mitigate the resulting threats and to take advantage of the opportunities created. The proposed systems use the Functional Resonance Analysis Method (FRAM) for qualitative risk analysis of multifunctional flood defences. The analysis results are used to identify the threats and opportunities that need attention during the design of a multifunctional flood defence and to propose recommendations for how to address them.

Keywords*:* Multifunctional flood defences, Risk analysis, Socio-technical system, Flexibility, Uncertainty,Functional modeling Dependence.

1. Introduction

Multifunctional use of flood defence is proposed as a promising solution for dealing with the conflicts of flood protection and urban development as well as enhancing the cost effectiveness of reinforcement interventions [1].

Both the negative and positive impacts arising from these changes have to be taken into account to plan not only for minimizing the unwanted negative outcomes, but also to take advantage of the opportunities for improving the system performance [2, 3]. Conducting such a risk analysis early during the conceptual design phase can help the designers to proactively identify and handle these potential risks.

Multifunctionality can induce dependencies between the system components, which leads to complexities in risk analysis of such a system [4]. Once the functions are combined, they become part of a broader socio-technical context in which the well-/mal-functioning of the system depends not only on its technical performance, but also on the role of humans as operators, inspectors, and users of the system [5].

This research investigates the application of the Functional Resonance Analysis Method (FRAM) [6] for qualitative risk analysis of multifunctional flood defences. The term 'risk is used in this research to denote the uncertain outcomes that could be either positive or negative. The objective is to identify how the dependencies caused by the multifunctional use of flood defences can strengthen or weaken the desired performance of the system when there is a change in its working environment. FRAM is selected because it enables modeling both negative and positive events resulting from (intended and unintended) dependencies between the functional components of a multifunctional flood defence. The premise of FRAM is based on the generic steps of the system analysis to analyze the system functions by breaking apart the system into the functional components that are relatively well known, identifying the dependencies between the components, and investigating the impacts of the dependencies on system performance.

2. Background Theory

2.1. System Definition

From a structural point of view, [7] state that A multifunctional flood defence often consists of at least two objects: a water retaining structure for flood protection and a secondary structure placed in close vicinity of the flood defence which is not intended for flood protection. a multifunctional flood defence as a combination of functions such as transport, housing, agriculture, nature and recreation with the primary function of flood protection.

In this proposed system, the working definition of multifunctional flood defence refers to:

A zone that is primarily used for flood protection, but serves other non-water retaining functions (e.g. transportation, housing).

In principle, there is no limit to the number and type of functions that can be combined with the flood protection function. The combination of the function(s) is considered as multifunctional only if the structure of the secondary function (secondary object) is located partly or fully in one of the standard flood protection zones around the flood defences.

2.2. System dependencies

Multifunctionality does not only refer to a high concentration of several activities in a relatively small space, but also implies that it induces various types of relationships between the combined functions. If these created relationships are such that the state of one function of the system becomes reliant on or is influenced by the state of another one, then there is a dependency between them [8].

Ref. [9] classifies the intended relationships among the infrastructure components based on the mechanisms that connect them. Ref. [10] selects and indicates the physical (or functional) and geographical relationships as the most relevant types of dependency to be considered for water related infrastructures. These two types can also reflect the intended relationships between the components of a multifunctional flood defence, which are caused by combining and relating the functions and/or co-locating and connecting the associated structures.

Physical dependency refers to the situation in which the state of one function is intentionally designed to be dependent on the other functions. Geographical dependency occurs where the structural elements of a system are co-located in such a way that a local environmental event can affect all elements.

3. Methodology

The effectiveness of flood defences in reducing the risk of flooding is well-known although ensuring their desired performance involves significant challenges. One challenge is that present methods are not able to fully describe and predict the performance of a single flood defence under controlled conditions[11]. Another challenge is that the operating environment of flood defences changes constantly and is associated with uncertainties. Combining other functions with the primary function of flood protection further complicates the matter. The intended physical and geographical dependencies add new relationships between the system components and their operating environment, which can influence the desired performances of a multifunctional flood defence. Identifying these potential dependencies during the early development phase of multifunctional flood defences can help to improve the system design to handle unexpected outcomes.

3.1. The 'Functional Resonance Analysis Method'

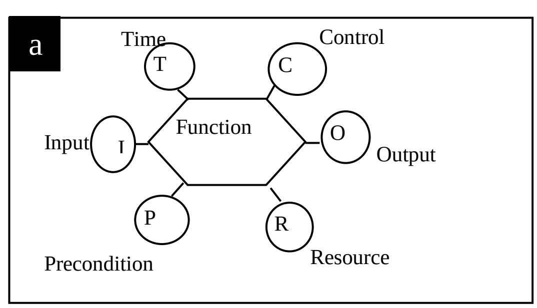
FRAM uses a novel representation of the system performance based on the concept of functional resonance that originates from wave theory in physics. The term 'stochastic resonance' is transferred to describe the variability of performance of the functions within a sociotechnical system. It is claimed that the inevitable changes in a system and its working environment can lead to variability in the performance of individual functions. Propagation and aggregation of the performance variability caused by the dependencies between the functions may result in unintended outcomes. The functional model of the system is developed and used to identify the potential dependencies between the functions for specific (retrospective or prospective) scenarios. In short, FRAM is implemented in four steps as follows:

Step 1: Identifying and describing the functions

The premise of FRAM is the decomposition of the system into its functional entities, including the technical, operational, and organizational activities, which are involved in the day to day work of the system to succeed. The functions are characterized by the six aspects of Input (I), Output (O), Precondition (P), Resource (R), Time (T), and Control (C) and are visualized as shown in Fig. 1a. The six functional aspects are linked together to address the dependencies between the human technical activities during the specified scenarios as shown in Fig. 1b.

Step 2: Characterizing the performance variability

The second step of FRAM determines the possible sources and types of variability for the individual functions. The potential sources of variability in the outcome of a function can be related to change in one of the six aspects of the function itself; the aspects of the other functions; and the operating environment. The type of variability indicates how the outcome of a function may change and is characterized qualitatively in terms of a time (too early, on time, too late, not at all) and precision (precise, acceptable, and imprecise).



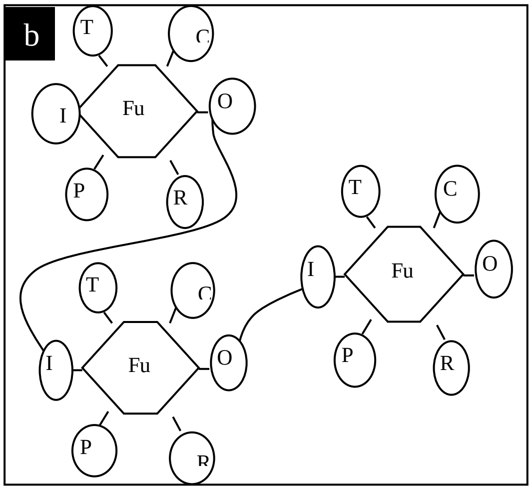


Figure.1. (a) The graphical representation of the six functional aspects; (b) a demonstration of the functional dependencies as represented by the connecting lines.

Step 3: Aggregation of performance variability

This step is aimed at identifying the potential dependencies that propagate the variability and the aggregation of variability leading to unexpected (either positive or negative) outcomes based on the description of a particular scenario. This aggregation is also called 'functional resonance'. Any detected possible functional resonance, for the specified event (or scenario), is taken as a discernible 'signal' of a threat or opportunity.

Step 4: Responding to performance variability

The functional model of the preceding steps is used to identify proper strategies (elimination, prevention, protection and facilitation) to cope with possible occurrences of uncontrolled performance variability. Thus far, FRAM has been predominantly applied to retrospective safety and accident investigations, where the primary focus is on variability of human-centered functions.

4. Proposed System

The proposed system use FRAM is because it is well suited for representing the complex relationships between the functional components of socio-technical systems [12].This method is used to derive the potential dependencies between the functional components of a multifunctional flood defence in order to provide input for risk analysis [13,14], demonstrating both the threatening and opportunistic outcomes[15,16].The FRAM method has the limitation because of the lack of sufficient information and expert availability. So this proposed system aim to get more detailed analysis of flood defence.

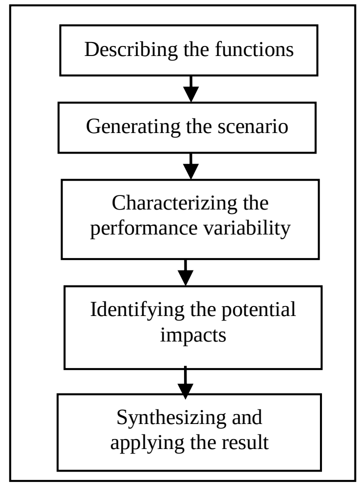


Figure 2. Proposed system design

5. Conclusion

The objective of system is to enhance the risk analysis of multifunctional flood defences by developing a tool for the system designers to explore how the flood protection and secondary function can mutually impact each other positively and negatively. Functional modeling of multifunctional flood defences by developing a tool for the system designers to explore how the flood protection and secondary function can mutually impact each other positively and negatively. This system examines the application of the Functional Resonance Analysis Method' (FRAM) to the risk analysis of multifunctional flood defences. For the purpose of the, FRAM is customized into five steps for describing, characterizing and visualizing the functions of a multifunctional flood system and their dependencies. The method provides a qualitative tool for a broader view, analysis, and visualization of many imaginable internal and external changes to the system including various types of human, technical, and environment interactions. The proposed system aim to get more detailed analysis of flood defence.

6. Reference

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