Axiomatic Design

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A Framework of Designing Reliable Disaster Response Operation Using Axiomatic Design

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Abstract. In an attempt to reduce the number of casualty when disastrous events occurred, the existence of reliable disaster response is becoming urgency. Nevertheless, earlier studies in disaster management field are rarely discussing this important issue. In narrowing down this research gap, in this paper we presented a framework in designing reliable disaster response using axiomatic design. At first, customers and functional requirements and design parameters of reliable disaster response is presented and followed by mapping those parameters into structural and process domain of disaster response operation. Then, functional requirement matrix representing relationship of those parameters is presented. Next, a framework in representing elements and relationships among four parameters of axiomatic design in the domain of disaster response process is provided. Opportunities for further research from this initial study are also presented.

INTRODUCTION

In the last decades, a number of natural disasters occurrence frequencies and their casualties are growing increasingly at an alarming rate (Whybark, 2016). In responding to this crucial situation, scientific endeavor intended to improve capability to disaster response management is necessary (Musani and Shaikh, 2016). A study by Goldschmidt and Kumar (2016) stated that scientific inquiry to prevent disaster response failure is needed to save large number of disaster victims. In order to gain success in responding to humanitarian event intervention, creating reliable response operation is becoming very important priority. However, the existence of studies in improving reliability of operation is mostly coming from for profit-oriented operation such as (Bhamare *et al.,*2007) and Zio (2009) and leaving reliability improvement endeavor in not for profit sector such as humanitarian operation as a vacant research area. At the other side, improving disaster response activity at design stage is strongly affecting to successfulness on the deployment of emergency resources at the operational stage. Inspired by the benefit offered by axiomatic design method in profit-oriented sectors, the application of axiomatic design in humanitarian response

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operation is believed very beneficial to improve manageability of disaster response operation. However, none of the previous research in axiomatic design studies is dedicated in the humanitarian context as most of axiomatic design studies as elaborated in brief by (Sadeghi *et al*., 2017) and Rauch *et al*., 2017 which are focused on for profit oriented operation.

Motivated by this discrepancy, in this study we present a conceptual framework to design reliable disaster response operation using axiomatic design method in narrowing down above gap. The structure of this paper is in the followings; in section 1, an overview of disaster, emergency and humanitarian response operation and axiomatic design is presented and followed by elaboration of each element of disaster response in section 2. Section 3 discusses conceptual framework in integrating axiomatic design into response operation. Discussions on the framework of the model integrating axiomatic design into emergency operation is presented in section 4. At the end, conclusions and suggestions for future research endeavors are presented in section 5.

Overview of Disaster and Emergency Response

Disaster

Following John *et al*., (2012), disaster is defined as the occurrence of unintended event causing widespread adverse impact and severely disturbing societal activities. According to its causing factors, disasters are generally classified into human-made and natural made disasters. The example of human -made disasters are in the form of terrorisms, political and refugee crises. Meanwhile, for natural-made disasters, the examples are in the form of tsunamis, hurricanes, typhoon and any other natural caused disasters. Classification and characteristics of disaster modes based on recovery duration and their occurrence characteristic are presented in **TABLE 1.**

TABLE 1. CLASSIFICATION AND CHARACTERISTICS OF DISASTER MODES (Kumar and Havey,2015)

	Recovery Duration	Human -made	Natural
Slow onset	Short (1-6 months)	Political crisis,refugee crisis	Famine,drought
	Medium (6-12 months)	Political crisis, refugee crisis	Famine,drought
	Long (more than 1 year)	Political crisis, refugee crisis	Famine,drought
Sudden onset	Short (1-6 months)	Terrorist attacks	Hurricanes,floods, earthquakes,tsunamis
	Medium (6-12 months)	Terrorist attacks	Hurricanes,floods, earthquakes,tsunamis
	Long (more than 1 year)	Terrorist attacks	Hurricanes,floods, Earthquakes,tsunami

A complete typology of disasters can be referred to the work of Kumar and Havey (2015). Being unintended events occurred, in addition to causing large number of casualties, disaster event occurrence triggering to many losses including economic, psychological and social losses.

Emergency Response Operation

Among four steps in disaster life cycle, disaster response is becoming the first step when disastrous events occurred (Mackay *et al*., 2019). According to Al-Dahash *et al*., (2016), disaster response as one exemplar of emergency response is defined as an activity to collect and act immediately upon the disaster events occurred. Its goal is related to help the victims and reduce the impact of disasters to the lowest level. Driven by the escalation of disaster occurrence in the last two decades, improving understanding on how to undertaking emergency response better is getting more important. In addition, driven by the unique characteristics of humanitarian situation as described by Choi *et al*., (2010) demanding on the need to design performable humanitarian response operation under uncertainty. As intended to save human lives in emergency situation, reliable emergency response is one of key factors affecting the success of response operation. In this regard, decision makers need to know on metrics representing reliable response operation and how to deploy those measures in a supply chain-oriented operation. Working collaboratively among other stakeholders in disaster response, quality of coordination and collaboration are other important factors toward realising a successful response operation. To achieve effective emergency response operation, management of the four aspect of emergency components are prerequisite. Those are concerning on emergency organization, emergency resources, emergency plans and emergency information.

Emergency organization refers to the organizing body responsible to undertake emergency operation. Those are governmental bodies, police, fire service officers, volunteers, donors, military officers and many other related organizations. Emergency resources concerning on any basic materials needed to undertake emergency activities can

be executed. Those basic materials are including manpower, utensils, data and all facilities needed for running an emergency activity.

Emergency plans relate to any plan to prevent and deal with the occurrence of disasters. Well planned emergency plan is becoming important to secure success in any humanitarian response operations.

Emergency information.

Emergency information refers to the processed data such as figures, images, texts, and so on in the emergency response process for urban rail transit. This is the important foundation of emergency decisions and emergency rescue. Emergency information is defined as any necessary data needed to operate emergency operations. Reliable emergency response will improve coordination among organizations involved in response operation.

A framework describing relationship among four aspects of emergency response is given in **FIGURE 1.**

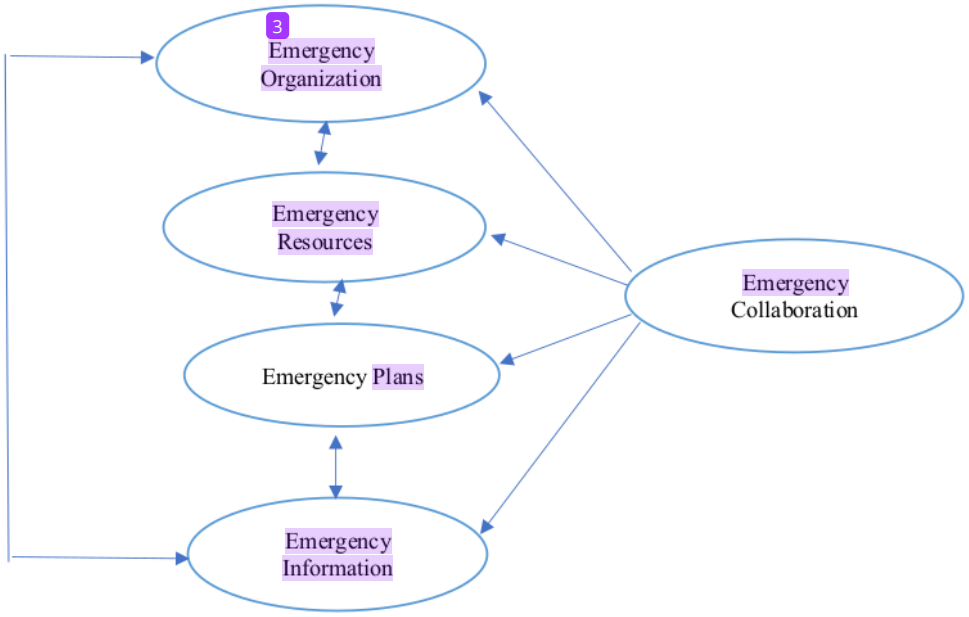

FIGURE 1. A Framewok of Emergency Response (Zhou et al., 2016)

OVERVIEW OF AXIOMATIC DESIGN

Becoming a process entails to realization of product and process in line with customers' requirements, following Gui and Huang (2004); design is defined as activity process in translating customers requirement into product and process specifications. According to Coelho and Mourayo (2007), the conventional design thinking is following these sequential paths; conceptual product, design product and process design. Meanwhile, axiomatic design which developed in 1970s to govern a good design activity process. It is intended to provide a scientifically basis to design product, process and system based on rationality. Intended to fulfil customers' requirements into product and process specification based on logical design thinking, axiomatic design method is based on the four domains in lying its foundation. Those are namely customer, functional, physical and process domains Babur *et al.,* (2016) and Palleti (2018). The first domain, the customer domain relates to determination of what are intended by customers (voice of the customers). The second domain, the functional domain relates to linking what are intended

by the customers in term of functional requirements (FRs) and constraints inhibits functional requirements realization. The third domain, the physical domain relates to link design parameters to meet with functional requirements' specification. Design parameters describe on how to fulfil functional requirement intended by the customers. At last, the fourth domain, the process domain relates to representation of development of the design parameters into the process domain. In operating its principle, axiomatic design involves systematic flow and decomposition process. Furthermore, axiomatic design uses two axioms, independence axiom and information axiom. Independent axiom is intended to determine the path which should be followed during the process. The independent axiom declares that each of functional requirements must be maintained independently. The second axiom, the information axiom is intended to determine the most suitable design alternative considering to functional requirements. The information axiom states the choice of the design candidate will be chosen to the design alternative with the smallest information content. Figure 1 represents the four domains of axiomatic design.

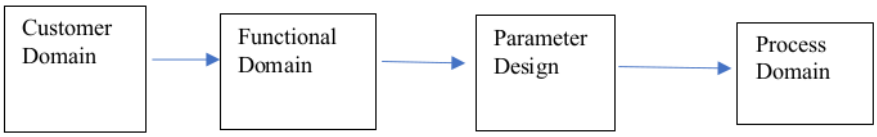

FIGURE 2. The Four Domains of Axiomatic Design

Framework in integrating Axiomatic Design into Disaster Response Operation

As stated that this paper presented on framework in designing reliable disaster response operation, the steps to integrate axiomatic design into design of reliable disaster response is provided in the followings.

Determining Customer Domain

Customer domain in this context related with activity to identification on all customer needs or the voice of the customers. In other word, all expectations regarding on what customers want during disaster response operation is undertaken. The result of this steps are series of customers' expectations. Different from commercial situation in which customers are the recipient of the good and services provided, the customers in the context of disaster response are the victims and the donors. In relation with the goal to create reliable humanitarian operation, voice of customers representing reliable response operation is declared in this step.

Determining Functional Domain

When customer needs have been determined, the next step following the axiomatic design is determining functional domain. In this step, decision makers link all customers' expectations into functionality of the product, process or system will be designed. Functional domain shows relationship between customers expectation and related function to realise those customers' expectation. In relation with the context to create reliable humanitarian response, voice of customers obtained in earlier step then mapped into functional domain of the response operation.

Determining Parameters Domain

Parameters design refers to specification must be attained to realise what customers want upon linkage between customers' expectations and functional requirement is obtained. In this step, disaster response reliability specification is the determined and mapped with the relevant function of the response activity.

Determining Process Domain

The fourth domain the process domain, relates to linkage between parameters and process domain. In the process domain, designer will be able to inform which process relate to parameters specified. this last domain relates to linkage between specified parameters goals and related process correspond to reach those specifications.

A framework describing relationship of above steps is provided in Figure 2 and output of each step of axiomatic design is given in Table 1.

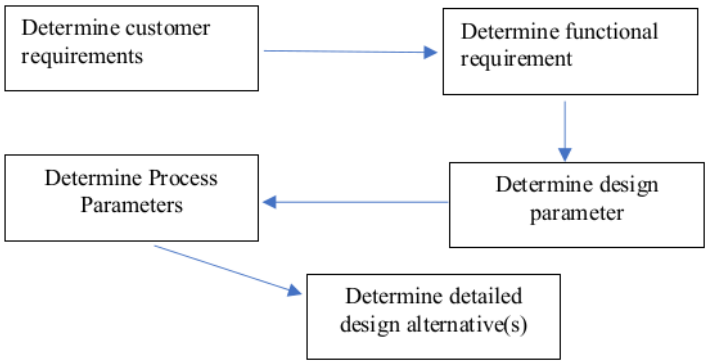

FIGURE 3. A Framework Axiomatic Design of Reliable Response Operation

Looking at FIGURE 2, the framework is commenced by determination on the customers need or voice of customers followed by identification of functional requirements, determination on design and process parameters. Meanwhile, as presented in TABLE 2, all parameters representing reliability measures relates to disaster response are the output of each step of axiomatic design.

TABLE 2. Steps and Output of Axiomatic Design

No	Step	Output
1	Determine Customer Requirement	Reliability Measures on Disaster Response
2	Determine Functional Requirement	Functional Parameters representing reliable disaster response
3	Determine Design Parameters	Design Parameters of reliable response
4	Determine Process Parameters	Process Parameters of reliable response

Integrating engineering design for reliability is important step to realize reliable design of disaster response operation. Instead of relying only on reactive approach in preparing emergency response, in this paper a forward step in design reliable response operation based on axiomatic design-based approach is presented. Using this approach enable emergency planner realising customers-based emergency operation be realised into practical situation.

CONCLUSIONS

Reliable disaster response is the first important step to reduce the possibility on increasing number of casualties when disastrous events occurred. However, the number of studies intended to improve design for reliable disaster response representing not for profit sector are very scanty in literature. Motivated by this research gap, in this study a framework in designing a reliable disaster response using axiomatic design principle is proposed. By embedding the principle of axiomatic design, designer of emergency response operation enables to improve decision process efficiency instead on basing on the sequential design process. New research chance from this initial effort is viable in several directions. First, applying the conceptual framework into design practice will provide insights on appropriateness of the framework at practical situation. In second path, integrating axiomatic design and robust

design principle in design for robust and reliable emergency response operation is missing in references and demanding for further investigation.

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