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An Application of Anticipatory FMEA for Preventing Failures in Humanitarian Response Operation

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Abstract. In an attempt to reduce the number of casualties when natural disasters occurred, the existence of reliable disaster response is becoming urgency. Nevertheless, earlier references in disaster management field are rarely discussing this importance issue. In narrowing down this research gap, in this paper we presented a framework in designing anticipatory Failure Mode and Effect Analysis (FMEA) in preparing anticipatory action preventing derailment of humanitarian response operation. An introduction and procedures to implement anticipatory failure mode and effect analysis is presented using case example. The result of applying the model enable to indicate potential riskiest failure to be alleviated. Potential research opportunities from this study are also presented.

INTRODUCTION

Categorized as one of the most countries prone to the occurrence of natural disasters, investigative effort to prevent reoccurrence of failure in undertaking humanitarian response operation in Indonesia is very important for saving number of lives and preventing property damage. However, despite of this unfavorable situation, studies intended to improve manageability of disaster response operation in Indonesia context as elaborated by [1] is neglecting effort to advance studies in preventing the reoccurrence of failure in disaster response operation. In preventing failure in undertaking response operation, identifying all possible failure is an essential activity. Unfortunately, relying on reactive failure assessment method using conventional FMEA (Failure Mode and Effect Analysis) method is insufficient to deal with all potential failures in response operation and there is a need to develop a proactive failure assessment method [2]. However, scientific study in applying FMEA in disaster response operation as exemplified by the work of [3] is still based on reactive approach in identifying failure mode in response operation. Reliance of reactive approach in determining the mode of failure occurrence is disadvantageous since it is possibly making the system under study is vulnerable against unpredictable events, especially to the Black Swan type failure events [4].

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In preventing this research gap, in this study an effort intended to prevent the reoccurrence of disaster response failure is presented using anticipatory FMEA model. This paper intends to introduce and present the use of anticipatory FMEA model and its application in the context of disaster response operation. This paper is written by following structures. Categorization and exemplar variable of failure in humanitarian response operation is presented in section 1. Next, introduction and elaboration of anticipatory FMEA components and its framework model are provided in section 2 and section 3 respectively. Finally, discussions on the proposed framework is presented and followed by directions for future studies in section 4 and 5.

HUMANITARIAN RESPONSE OPERATION AND ITS FAILURE DIMENSIONS

Overview of Humanitarian Response Operation and its Failure Categorization

Disaster (humanitarian) response operation is series of immediate activity intended to help disaster victim after the occurrence of a disastrous event. It is the second step in the life cycle of disaster. Undertaken collaboratively with other organizations, collaboration and coordination are two key success in performing humanitarian operation. In similar with manufacturing literature, disaster response operation may suffer from failure. In humanitarian response operation context, failure is defined as inability of response operation fulfilling the need of disaster victims. According to [5], failure in humanitarian response is characterized by 3R logistically oriented failures. Those are consisting of wrong place, wrong time and wrong materials when delivering aid to the victim.

Anticipatory Failure Mode and Effect Analysis (FMEA)

FMEA as an abbreviation from Failure Mode and Effect Analysis (FMEA) is an engineering method intended to identify failure mode may occur in a product, process, system and design, evaluating criticality of their impacts using metric called Risk Priority Number (RPN), and finding solutions to prevent reoccurrence of failure. Becoming risk assessment tool, the RPN as risk metric is obtained by multiplying the scale of failure occurrence, detection and severity. For details on procedures and scale of those three indices can be referred [6]. As the name imply, anticipatory FMEA is an advanced version of FMEA by inclusion of the Anticipatory Failure Determination (AFD) method which progressing failure analysis proactively. Different from traditional FMEA which applied based reactively to the occurrence of failure, Anticipatory FMEA is based on the premise on how designer can make failure conditions occur. In similar with its predecessor, AFD intends to find any potential unintended events disrupting the operation of system based on the available resource [7]. Progressing failure assessment method for finding root cause of unintended events, AFD method is integrated method coming from integrating of the AFD -1, AFD-2 and AFD-3. The AFD -1 is used to deal with the occurrence of failure already occurred. Meanwhile, the AFD-2 relates to prediction on the occurrence of failure and the AFD-3 dealing with human, organizational errors and other causal factors. The steps to perform anticipatory FMEA is generally consisting of the stages, identification of system and its interrelationship system function, determination of system function and corresponding resources to make system functioning, and determining combination of functions and resource to make system malfunction, accessing impact of direct and indirect system failure effect and finding solution to curb the root causes of system malfunction. The steps to perform the anticipatory FMEA is given in **TABLE 1.**

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TABLE 1. The Step to Perform Anticipatory FMEA

No	Step
1	System Identification
2	Determining system operational cycle
3	Modelling system function including its sub system interrelation
4	Determining list of functions
5	Identifying available resource
6	Determining combinations of functions and resource to make failure
7	Estimating direct and indirect failure effect
8	Searching for generic failure causes
9	Ranking potential failures and accidents

One distinct feature of the Anticipatory Failure Mode and Effect Analysis is identification of resource availability to make functionality success to system, product, process, etc to occur. According to [8], perspective to generate potential failures is becoming distinct difference between AFD and other method such as HAZOP. In conventional failure assessment method, failure prediction process is commenced by linear thinking from system function articulation leading to what failure may occur when the system function deviated. At the opposite, the AFD proposed failure inventing approach by using how to make system failed in performing its functionality and resources needed to make it failed. Reliance on this approach making system designed using anticipatory FMEA more robust against unpredicted failures. Becoming risk assessment tool, the anticipatory FMEA basing on the three risk parameters, the failure occurrence scale, failure detection scale and severity of failure scale as foundation to determine the score of risk metric. The multiplication of those parameters is becoming the score of the Risk Priority Number (RPN).

Risk Priority Score (RPS) = O x D x S (1)

TABLE 2. Representation of the Anticipatory FMEA Scale

Rating	Linguistic Interpretation	Occurrence Scale (O)	Detection Scale (D)	Severity Scale (S)
1-2-3	Low	The occurrence rate of failure is very low	Detection Capability to failure occurrence is very high	Severity of failure effect is low
4-5-6	Moderate	The occurrence rate of failure is moderate	Detection Capability to failure occurrence is high	Severity of failure effect is moderate
7-8	Medium	The occurrence rate of failure is medium	Detection Capability to failure occurrence is medium	Severity of failure effect is medium
9	High	The occurrence rate of failure is high	Detection Capability to failure occurrence is low	Severity of failure effect is very high
10	Very High	The occurrence rate of failure is very high	Detection Capability to failure occurrence is very low	Severity of failure effect is catastrophic

Case Example

In order to show the applicability of the anticipatory FMEA in disaster response operation, a case example [9] is used for illustrative purpose. First step in disaster response is planning of emergency response to save lives of the disaster victim. **TABLE 3** presents the functional analysis of planning of emergency response and its related resource needed.

TABLE 3. Functional Analysis of Planning and Preparedness of Emergency Response

No	Disaster response Phase	Function	Resources Needed for Execution	Specific Resource
1	Emergency Planning	To provide fast, effective and efficient aid delivery to customers	Time	Time to prepare fleet, time to reach evacuation point,
			Space	Number of available vehicles, number and type of aids needed, Total number of disaster victims
			Energy	Fuel Sufficiency to deliver aids
			Information	Exact location and the number of the victims
			Governmental Policy	Clear governmental regulation to handle disaster

TABLE 4 and **TABLE 5** present the result of identifying direct and indirect potential failure in emergency planning of disaster response operation.

TABLE 4. Identifying direct potential failures in Emergency Planning

No	Disaster Response Phase	Function	Specific Resource needed	Potential Failure
	Emergency Planning	To provide fast, effective and efficient aid delivery	Time	Time insufficiency to prepare fleet
				Insufficient time to reach evacuation point
			Space	Insufficiency of fleet
				Unknown number of disaster victims
			Energy	Insufficiency of fuel to run fleet
			Information	Unknown location of evacuation points
			Governmental Policy	Unclear responsibility to handle disaster evacuation

TABLE 5. Identifying Indirect Potential Failures in Emergency Planning

No	Disaster Response Phase	Function	Specific Resource needed	Potential Indirect Failure
1	Emergency Planning	To provide fast, effective and efficient aid delivery	Coordination among organizations involved in emergency response	Poor coordination among organizations
				Insufficient time to reach evacuation point
			Regulation	No clear regulation to between government and private sector for logistical supports for the victims
			Time Management of Disaster	Poor Time Management of Disaster

Table 6 presents the risk criticality measurement based on the RPN Score. The parameters of the potential failure occurrence, detection and severity scale are multiplied to obtain the RPN Score of each potential failure events.

TABLE 6. Criticality Index of Direct and Indirect Potential Failures

No	Potential Failure	Anticipatory FMEA Parameter			
		O	**D**	**S**	**RPN Scale**
1	Insufficient time to reach evacuation point	3	2	3	18
2	Insufficiency of fleet	5	2	3	30
3	Unknown number of disaster victims	5	5	2	50
4	Insufficiency of energy to run fleet delivering aid	3	3	3	27
5	Unknown location of evacuation points	5	3	3	54
6	Unclear responsibility to handle disaster evacuation	5	2	5	50
7	Insufficient time to reach evacuation point	4	2	3	24
9	No clear regulation to between government and private sector for quick distributing logistical supports for the victim	4	2	5	40
10	Poor Time Management of Disaster	4	2	3	24

From Table 6, based on the RPN scores, three riskiest events in disaster response planning are identified. “Unknown number of disaster victims”, “Unknown location of evacuation points” and “Unclear responsibility to handle disaster evaluation” are the three potential failure factors making disaster response fragile. The root causes of those critical failures must be identified to prevent failure in undertaking disaster response operation based on case example.

CONCLUSIONS

Anticipating failure occurrence is very important to prevent failed disaster response operation. However, most of earlier failure prevention studies in disaster response operations are accomplished in reactively way causing possibility of increasing victims due to unexpected failures. In this paper, an anticipatory FMEA model is presented and followed by an example in using it in response operation. Inclusion of functional and resource analysis to make failure happened enable decision makers preparing necessary counter measures preventing derailment of response operation. Considering that this study is based on hypothetical failure factors as basis to demonstrate its applicability, the next research path to follow is validating the proposed anticipatory model in practical situations as first research

opportunity. The second research direction is concerning on establishment of method to consider failure propagation mechanism into the Anticipatory FMEA model.

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