Print ISSN: 2321-6379
Online ISSN: 2321-595X
DOI: 10.17354/ijssl/2017/79

Original Article

Value Engineering Solutions using the Technique of Fault Tree (Case Study: Shahriyar Mashhad's Tower)

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Abstract

Each year, a major part of the national budget allocated to constructional projects. One of the most important constructional projects in major cities is already high-rise buildings. Due to the incensement of urban populations and land scarcity, high-rise building is on the rise day by day. Available costs in these types of projects are more than usual constructional projects. Shortcomings and different problems caused the length of the project be more than predictions made in the initial planning of the project, which resulted in many problems for the country. High system reliability analysis, implementation and performance because of high importance requires transparent way to decide on what type of procedure is likely to deal with possible damages. Among the methods for assessing reliability, fault tree analysis is one of the effective ways. This method is a deductive top-down method, a method in which a poor state of the system is analyzed. This paper first introduces the fault tree analysis. In the following, Shahriyar tower's installation tree system error will be drawn. The Lack of adequate efficiency of system installations is considered the main event in fault tree and the occurrence and causes of system failure is based on view of construction experts, reviewing records system failures, recorded in the engineering organization Mashhad and study regulations, identification and more qualitative analysis of risk for the determination of shear at least done. With these efforts, quantitative analysis of fault tree for future research will be facilitated to the maximum reliability of the system and sensitive parts of the network for the management of significant value and solutions to improve performance of commercial project.

Key words: Fault tree analysis, High-rise buildings, Reliability

INTRODUCTION

The concept is very subjective, to different people, has several meanings. Consumer, defines it "best buy", for the manufacturer means "least cost" and for designer "highest performance" will be considered. It is not the abstract concept: in other words, the value means time, people, subject and condition. Value engineering is a set of organized and creative techniques for analyzing functions of product, service or project. It should be noted that the value engineering is not limited to providing solutions at a lower cost, but also it deals with new methods for achieving a superior product at a lower price. Value Engineering seeks to create innovative and economical solutions, generally through the following methods and trained groups, can improve product value: (Alerasoul, 1387). The value engineering team makes decisions in brainstorming sessions using different methods to assess the reliability of different systems in the project. Then, using the method of self-assessment and group experience achieves the ultimate solution. The proposed solution should be appropriate and reasonable balance between cost and good quality. One of the useful tools to understand the causes of system downtime, factors critical points system vulnerabilities, reliability analysis of the system, is fault tree analysis.

In this method which is a deductive method, is assumed that a failure occurred in the system and attempt to identify the effective factors of the damage. In the past, many researchers used error analysis methods in different industries to analyze system reliability and

Access this article online

www.ijss-sn.com

Month of Submission : 06-2017
Month of Peer Review : 06-2017
Month of Acceptance : 07-2017
Month of Publishing : 07-2017

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risk management capabilities. (Abdelgawad and Fayek 2011) the quantitative evaluation of events risk in the construction industry, using Fault Tree Analysis Technique with fuzzy logic presented (.[5] Hwang, Lai et al. 1993) traffic safety of rail using Fault Tree Analysis were evaluated. Rail accidents are considered as the main event by them and by drawing fault tree they reached to lowest level of human errors and failures and by analysis they identified the most critical factors in rail accidents ([1] Yuhua and Datao 2005) probability of failure in oil pipelines and gas using Fault Tree Analysis studied and crucial factors influencing the damage caused by subsidence and rupture were identified and examined [3].

Ghasemi et al., 5835 analyzed the risk of developmental projects analyzed using fuzzy fault tree [4]. Their risks and their fundamental causes in the project of construction of water transfer tunnels were identified and evaluated and to identify risk factors critical in increasing the time and cost of the project in order to control and manage them focus and studied respectively.

In this paper, we introduce fault tree, fault tree analysis, reliability and failure factors in order to rank the degree of importance, we have tried to draw the fault tree for water distribution network. For this purpose, events and causes of failure of water and sewage systems, based on the opinion of experts to review the records of system failure, recorded in the engineering organization in Mashhad study has identified by studying the laws and related articles [1, 6]. After drawing the fault tree, fault tree qualitative analysis to determine the minimum shear collections and identification of single points of failure often considered weaknesses and areas of focus for precautionary measures is done.

With these efforts, quantitative analysis of fault tree for future research will be facilitated to the extreme reliability of the system and sensitive parts of the network for focus of managers in the maintenance are identified and strategies for increasing reliability of network installations and systems are proposed.

In this paper, we introduce fault tree, fault tree analysis, reliability and failure factors in order to rank the degree of importance, it has been tried to proper error to draw water distribution network. With these efforts, quantitative analysis of fault tree for future research will be facilitated to the extreme reliability of the system and sensitive parts of the network to focus managers in the maintenance identified and strategies for increasing reliability of network installations and systems are proposed.

METHODS

Introduction Fault Tree

A fault tree is a graphic model of the combination of series and parallel defects that trigger the final event are already defined. This model is a reasonable graphical model in the field of errors. That the errors of a predetermined event or adverse conditions called the main event of errors or faults until they reached errors or damages that called causal factor or initiator.

According to this technique called fault tree techniques analogy that in this way, top-down and top-down assessment is carried out. The comparative analysis is assumed that the failure occurred in the system and attempt to identify the factors in these crashes occur. According to this technique called fault tree techniques analogy that in this way, top-down and top-down assessment is carried out. The comparative analysis it is assumed that the failure occurred in the system and attempt to identify the factors in these crashes occur.

This is difference in deductive and inductive methods is that AHP techniques and inductive methods such as FMEA, is assumed that an error occurred in the system and efforts are made to determine the effects on the performance of this fault system.

In fact, the inductive techniques deals with consequences in case of an accident. That is why the so-called inductive approach is called bottom-up approaches. In fact, this method can be used to determine the nature of the error system (ie, what errors may occur) while applying the deductive methods are applied to determine the occurrence of a system error.

In view of Fault Tree, the special symbols are used that this symbol can be broadly divided into 2 groups:

1. Event symbols: These symbols are used to indicate the type of events.
2. Logic gate symbols: these symbols are used to indicate the type of logic gate. logic gates cause the connection of final event to lower event on any tree. It represents one or more inputs are received, but only has one output. Boolean logic gates are in nature. Output events that occur when the input events occur in accordance with the laws of the gates.

They are only listed in Table 1 and a brief description about them is limited.

As mentioned, fault tree for calculating the probability of errors in a system that the breakdown of a main event or fundamental events of fault trees occur.

Table 1: Symbols used in the display fault tree

It is the highest point error event and the causative factors are identified and analyzed	The main event	
The primary initial error that needs no further elaboration	Base event	
Output occurs when at least one of the inputs occur	Gate "or"	
Which occurs when the output of all entries occur	Gate "and"	

Decomposition process will continue until the foundations are independent events. To calculate the probability of final event, the possibility basic events must be obtained.

In other words, after the FTA with the risk of grounding can be achieved probably the main event. Figure 2 shows a sample fault tree. In this figure, TE represents the main event, GE central events and BE, which is based events link between OR and gates represent the community (U) and Share (∩). The event higher, lower output and event input gate is a gate. Mark gate input events indicate the type of relationship which is required for output event.

Fault Tree Analysis

Fault Tree Analysis can be both quantitatively and qualitatively or theoretical introduction, which continues to be addressed.

Qualitative analysis

Including qualitative fault tree analysis to determine the sets of shear events is final. Shear set some basic events, which all occur if an event occurs and set the final cutting shear with at least a minimum number of events is initiated. One of useful information that can be obtained from minimum shear collections, identify the fault is single or one situation. Often it is considered weaknesses and the areas of focus for prevention and promotion degrees.

Common method for obtaining shear collections is minimal use of Boolean algebra. For example, in Figure 2, the main error occurrence with respect to the events center and the base, the type of gate and the use of Boolean algebra formulas (1) to (6) will be:

$$TE = GE_1 \cup GE^2 \cup GE_3 \quad (1)$$

$$GE_1 = BE_1 \cap BE_2 \quad (2)$$

$$GE_2 = BE_1 \cup BE_3 \cup BE_4 \quad (3)$$

$$GE_3 = BE_5 \cap BE_6 \cap BE_7 \cap BE_8 \quad (4)$$

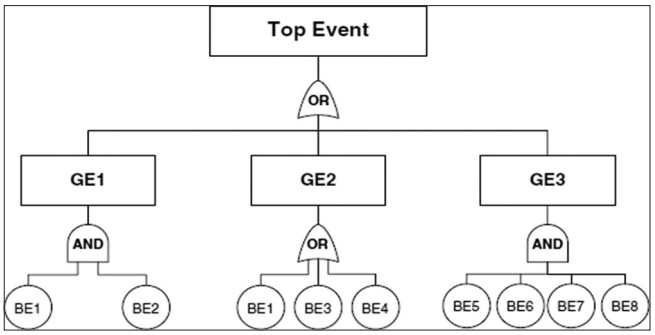

Figure 2: An example of fault tree

$$TE = (BE_1 \cap BE_2) \cup (BE_1 \cup BE_3 \cup BE_4) \cup (BE_5 \cap BE_6 \cap BE_7 \cap BE_8) \quad (5)$$

$$TE = (BE_1 \cap BE_2) \cup BE_1 \cup BE_3 \cup BE_4 \cup (BE_5 \cap BE_6 \cap BE_7 \cap BE_8) \quad (6)$$

You can now specify a minimum shear sets that are displayed with MCS:

$$MCS_1 = BE_1 \cap BE_2$$

$$MCS_2 = BE_1$$

$$MCS_3 = BE_3$$

$$MCS_4 = BE_4$$

$$MCS_5 = BE_5 \cap BE_6 \cap BE_7 \cap BE_8$$

MCS1, MCS2, MCS3, MCS4 and MCS5 are shear sets that are at least Mcs1 reveals that if BE1 and BE2 occur together with the main event taking place. Mcs2, Mcs3 and MCS4 the order indicated that if critical events BE1, BE3 and BE4 each occur, the main event will occur and so MCS5 that if BE5, BE6, BE7 and BE8 to occur the main event of the will occur. So at least in this instance there are 5 sets of shear and BE1, BE3 and BE4 the single situation.

Quantitative analysis

Where the assessment of the quantitative determination are: 1) the probability of occurrence of the top event; 2) the probability of events occur mid-; 3) the probability of occurrence of each set of shear minimum and prioritizing collections shear; 4) determine the sets of shear dominant; 5) the importance of basic events, intermediate events and shear sets minimum and 6) the reliability of the system.

To obtain a final probability of occurrences of shifting base using at least the relationship (7) and (8) are used. The P probability, TE main event, MCSi shear collections at least, N number of minimal shear and BEj are the basic events.

$$P(TE) = 1 - \prod_{i=1}^{N} (1 - P(MCS_i)) \quad (7)$$

$$P(MCS_i) = \prod P(BE_j) \quad (8)$$

Reliability

The possibility of errors in the system and reliability, according to equation (9) communicate with each other. In this regard, R reliability and Pf error probability (the possibility of final event) in the system.

$$R=1-P_f \quad (9)$$

Importance of analysis

To determine the relative effectiveness of each event based on the occurrence of major importance index (IM) according to equation (10) is used. In this regard TE1 likely main event if all occurrences of a basic happen and TE2 likely main event if the event base (the degree of importance it-measure) does not happen (the probability is zero), is. To determine the importance of each basic event-based events can be prioritized to focus managers.

$$IM = \left(\frac{TE_1 - TE_2}{TE_1} \right) * 100 \quad (10)$$

RESULTS AND DISCUSSION

As mentioned in this article in order to achieve fault tree for network installations and ventilation systems for high-rise buildings such as Shahriyar Tower has investigated. The main event in the fault tree system downtime network device is intended, the occurrence and causes of system failure based on the opinion of experts, building facilities, reviewing records system failures, registered at the city of Mashhad and studying the regulations is identified.

With this effort, Fault Tree Analysis for future research will be facilitated to the reliability of the system as well as the critical network administrators to focus on the repair and maintenance to be determined and strategies established in order to increase system reliability.

The fault tree in Figure 3a is visible, the entire network of three sub-fittings, valves and pipes is assumed that failure in either can cause a malfunction in the system, so the failure of the three gates OR the failure of network connect (Figure 3a). For each of these three subsystems as well as fault tree has been drawn (Figure 3b-d).

As can be seen in the fault tree, 11 basic events are existed that the source of system failures can be seen in Table 2.

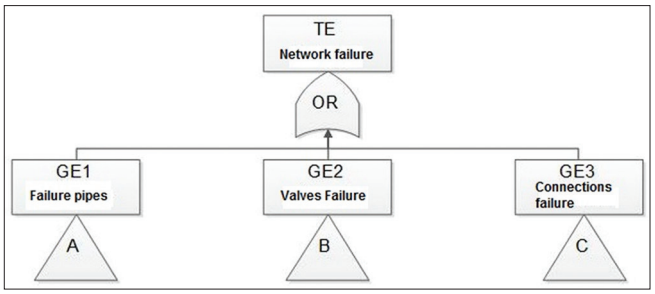

Figure 3a: A fault tree network downtime caused by failure of fittings, valves and tubing

Table 2: Water distribution network downtime fault tree basic events

Symbol base event	The base event
BE1	Exhaustion
BE2	Damage (intentional damage to civilian installations)
BE3	Incorrect installation
BE4	Inappropriate bed
BE5	High pressure
BE6	Hit machines
BE7	Burnout pipes
BE8	The poor washer
BE9	Wear washer
BE10	Burnout gates
BE11	Burnout connections

Table 3: Shear sets minimum failure fault tree water distribution network

Minimum shear collections	
BE1	Exhaustion
BE2	Damage (intentional damage to civilian installations)
BE3	Incorrect installation
BE4	Inappropriate bed
BE5	High pressure
BE6	Hit machines
BE7	Burnout pipes
BE8	The poor washer
BE9	Wear washer
BE10	Burnout gates
BE11	Burnout connections
BE3∩BE4	Incorrect installation and inappropriate bed
BE3∩BE5	Wrong installation and high pressure
BE3∩BE6	Installation and hit the wrong car

Qualitative analysis of fault tree with a minimum of shear is obtained which is visible in Table 3.

CONCLUSION AND SUGGESTIONS

As mentioned fault tree is a visual display of the logic of events and provides the main events in complex systems. By the fault tree analysis and sensitivity analysis, valuable information about critical events, that has maximum share in the events, are achieved. Using such an approach, the

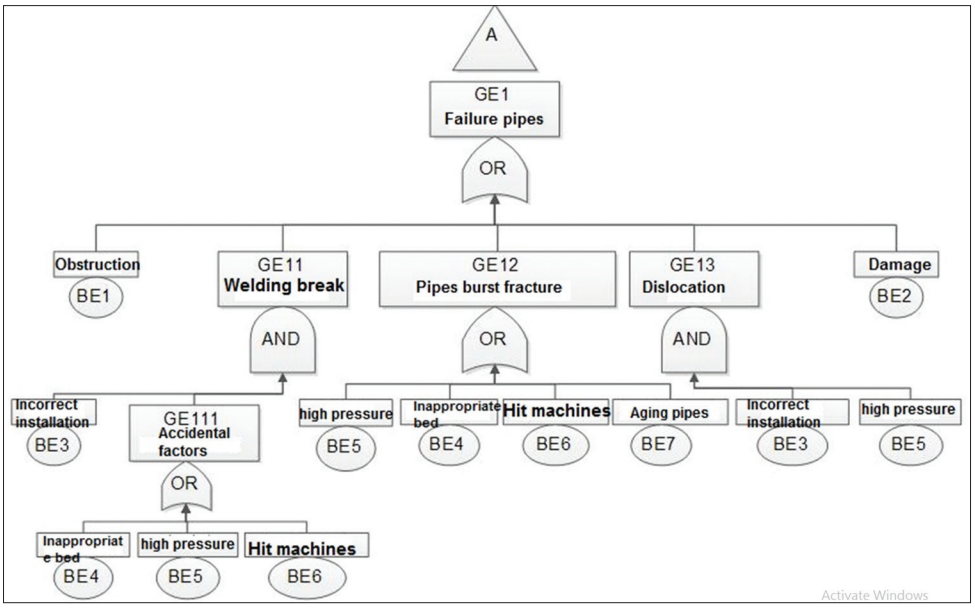

Figure 3b: Tubing fault tree damage

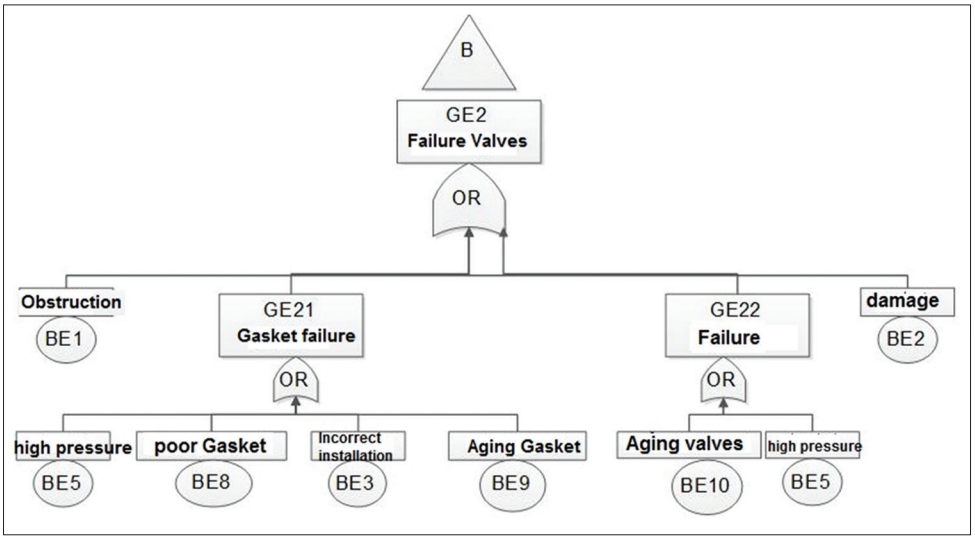

Figure 3c: Failure fault tree valves

project team can focus to build on preventive strategies to minimize the fundamental causes of the events.

In this article, it is the fault tree for network installations and conditioning of high-rise buildings are designed to enable better decisions and provide brainstorming session. For this purpose, events and causes of system failure based on the opinion of experts, reviewing records of system failures records and reviewing regulations are identified based on the events and factors are identified and drawn in fault tree. The main events of the fault tree in the water system failures, damage to fittings, valves and tubing is intended.

The fault tree qualitative analysis to find the minimum shear collections and identification of individual errors that often are the weak points have been carried out. This analysis identified at least 14 sets of shear. The 11-point disadvantage including burnout, causes damage (intentional damage civilian installations), installed incorrectly, improper bed placement of utilities, high pressure blasting machines, exhaustion (burnout pipes, gaskets, fittings and valves) and poor quality of washers were identified that should be the focus for precautionary measures.

With these efforts, the quantitative analysis of fault tree for future research is facilitated and it is recommended to quantitative analysis of fault tree using statistical data from the records of records destruction corporate facility reliability systems and critical points of the network facilities for most managers focus on the maintenance and

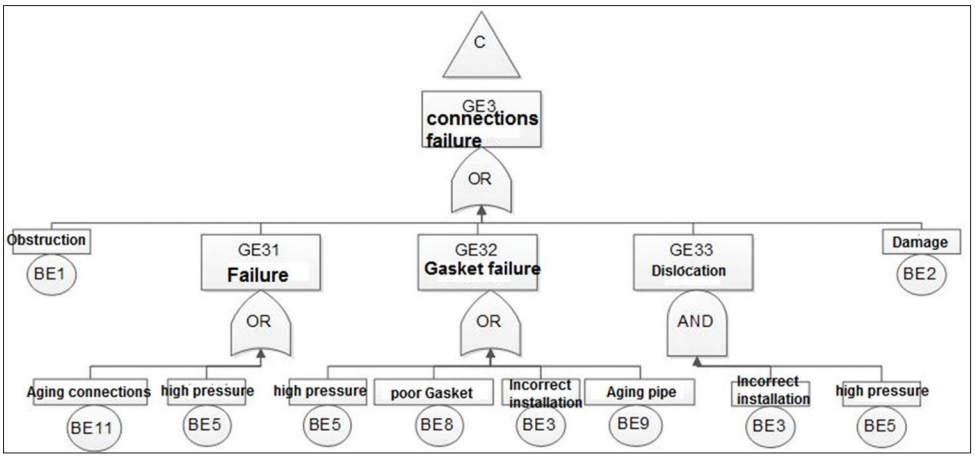

Figure 3d: Failure fault tree connections

ventilation installations to be determined and strategies to increase network reliability and conditioning facilities are offered.

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How to cite this article: Kheyraei H, Mohammadi A. Value Engineering Solutions using the Technique of Fault Tree (Case Study: Shahriyar Mashhad's Tower). Int J Sci Stud 2017;5(4):564-569.

Source of Support: Nil, **Conflict of Interest:** None declared.