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The Verification result of Permit to Work Assessment in Occupational Accident using Fault Tree Analysis

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Abstract. The objective of this paper is to elaborate and verified the results of the Permit To Work assessment that has been conducted using the Structural Equation Model (SEM) with Fault Tree Analysis (FTA) technique. The author used the Fault Tree Analysis to verify the result of five PTW elements i.e. Hazardous Activity, Worksite Inspection, Supporting Document, Work Description and Close Out. As it is known, the FTA is used to find the probability and cause of an accident or "Top Event". FTA is a relatively well-known technique used to find the probability of system failure. After the analysis using FTA technique, it was found that all the results of SEM and FTA gives the similar rank to Occupational Accident which is indicated that the result is correct and acceptable for this study. This is Part II of two paper, focusing on PTW Assessment result validation using Fault Tree Analysis.

1. Introduction

Permit To Work (PTW) is known as a special official document designed in such way, that being used intensively for control all the work activities in the Plant. With the increasing and importantly used of PTW in controlling Occupational Accidents at the Petrochemical Plant in routine and non-routine of daily activity, which in the earlier assessment of their element shows the impact of their element failures caused the Occupational accident. The study of the PTW on the industry showed that one the causes of occupational accidents is due to the weaknesses in PTW management in the industry in preventing the Occupational accidents. In the Part 1, the author analysed the PTW element failure using the Structural Equation Model (SEM) with AMOS graphic technique which gave a positive and definitive conclusion on the cause of occupational accidents at Petrochemical plants. The result of PTW element assessment has been achieved by using the SEM Amos results indicated that all the Permit To Work starting from the element of Hazardous Activity, Worksite Inspection, Supporting Document, Work Description and Close Out will be validated or evaluated using Fault Tree Analysis (FTA). The result from the Structural Equation Model) SEM) need to validate and verify that it will ensure the SEM result is correct and acceptable with the used data is accurate, quality, sensible and reasonable. In this Part 11, The Fault Tree Analysis (FTA) as a credible, quickness, accuracy and precision method used to validate the SEM Amos result that being performed earlier in Part 1. The FTA has been used by many researcher for describing in-depth analysis of cause and effect analysis of specific especially in chemical process, aerospace and others industry [1].

2. Methodology

2.1 Fault Tree Analysis (FTA)

Fault Tree are the deductive method extensively used in the risk of field analysis of process system [2]. It is the backward method to define top event or accident from various scenarios that can cause an accident. It also consist of basic event and intermediate event of an accident. The basic event cannot be defined anymore but the immediate event can be defined furthermore. The fault tree has two logic, the AND or OR gate. The AND gate is used for the process that occurs in parallel but the OR gate is used for either available options in the process can that may occur. The Fault Tree Objective is to provide of an integrated picture of some aspect of system operation beside it can be used to understand the level of protection for the design concept against failure. The use of the Fault Tree Analysis is to investigate the effect of safety barrier and the failure probability [3]. The various set of event that can lead to top event to occur are known as minimal cut set [4]. In Fault Tree Analysis the top event denotes or indicate the causal relationship leading to failure of safety barrier of the element and linked to failure of sub safety barrier or sub element. The FTA shows the sequence of logical relationships between elements of each stages in failure process [5]. The regression result of SEM Analysis can be analysed and verify using Fault Tree Analysis (FTA) [6]. The FTA is used to identify possible failure in a system and most commonly used for causal analysis in risk, safety and reliability. It provide a mean to identify the root cause of failure and to support the SEM analysis results. [7]. As per Process Accident Model which was developed with the series of safety element prevention failure and was placed in sequential order to depict the accident of hydrocarbon release accident [8]. The series of PTW element as barrier failure from the failure of the work description, hazardous activity, worksite inspection, supporting document and lastly the failure in closing out the PTW of a particular job for that particular time. The sequential of element failure is presented by using Fault Tree Analysis (FTA) and event tree diagram. The Top Event is the Occupational Accident, denote with the failure of all the safety barrier. [9]. In the FTA diagram, the second layer is associated with all the PTW element diagram on each of the PTW element also shown their escalating barrier failure.

3. Result

The item description is the item of each of PTW element construct in which the PTW element having five construct used in this study. The value of each items is being calculated using Fault Tree Analysis (FTA) formula of AND gate $P(A)= P(A_1)P(A_2)P(A_3)P(A_4)P(A_5)$. Formula OR gate $P(A)=1-[1-P(A_1)][1-P(A_2)][1-P(A_3)][1-P(A_4)][1-P(A_5)]$. Where the P(A) is the Top Event, $P(A_1)$ to $P(A_5)$ is a immediate event.

The calculating of error probability of each construct items can be calculated from the logical relationship between immediate event to top event of every layer of the Fault Tree Analysis and the result on each item as below:

Table 1. Results Fault Tree by items/construct

No. Items	Items Description	Assigned Probability (OR Gate)
	Work Description Construct	
1	Employee fill up necessary info in PTW	0.1947
2	No valid PTW for work in the Plant	0.1959
3	Job carried out with right PTW	0.1379
4	Employee attend PTW training	0.1374
5	PTW does not conflict with other job	0.2222
	Hazardous Activity	
6	Improper chemical handling without PPE	0.84727
7	Lifting work with high load	0.8812

8	Gas testing not done at excavation area more than 1.5 m	0.1149
9	Electrical /mechanical t/shoot on pump	0.1527
10	Corroded piping replacement	0.1877
	Worksite Inspection	
11	Worksite not being check before approve the PTW	0.6946
12	Scaffolding pipe not check	0.8668
13	No worksite check on from H2s and Mercury	0.0996
14	No lock out and tag out on equipment	0.1679
15	Blinding and spading without procedure	0.1794
16	De pressure and draining without procedure	0.2417
17	No N2 purging done before vessel entry for cleaning	0.2759
18	Temporary barricade not install	0.1870
19	No regular gas testing in confine space	0.1992
20	Regular area check not done during work in progress	0.1571
	Supporting Document	
21	JHA not attach when submitting the PTW	0.1959
22	No risk assessment done on before submitting the PTW	0.1954
23	Wrong physical isolation on equipment	0.1374
24	Switch not bypass and no record in logbook	0.2222
25	No gas test result attached with PTW	0.2223
26	Inspection on crane not done before entry the plant	0.1947
	Close Out	
27	Housekeeping not done after job completed	0.1948
28	No proper shift handover	0.1571
29	Operator does not check worksite after job completed	0.1572
30	No sign off of PTW after job completed	0.1034

For further detail the description of all the barrier and their sub barrier as per below:

3.1 Work Description Element Failure

This is the first element in Permit To Work. Under this element, the work leader need to fill-up all the necessary and right information in this section. Wrong info will cause the wrong interpretation about the work that need to be performed. In most cases some work leader has put the wrong information. Example of the wrong info such as the plant area of work and description of work that they want to do in plant. From the Fault Tree Analysis each, the error probability of each sub-element has been calculated using the OR gate. The probability value for wrong work info failure was 0.1974. The another four sub elements was the no valid work permit (0.1999), the wrong selection of PTW (0.13794), workers not attending PTW training (0.1374) and work conflict between work group (0.2222). The total probability failure is 3.12966 E-05.

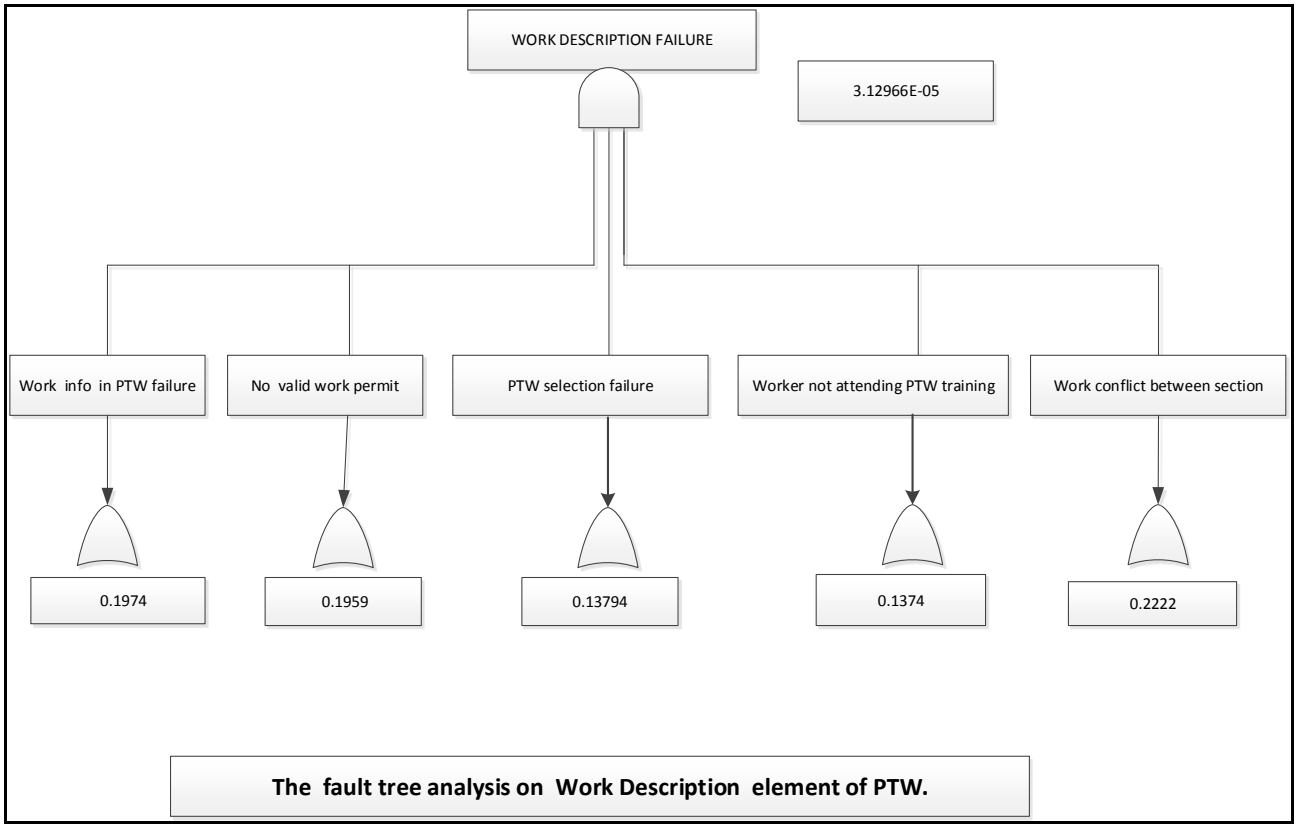

Figure 1. FTA for Work Description element

3.2 Hazardous Activity Element Failure

This is the second element of the PTW. The function of this element to ensure all the hazardous activities has been done the proper way. Example the checking and monitoring during hazardous activities in progress The example of hazardous activity in the Plant are working in confine space, lifting work, construction work during turn around, excavation, pig retrieval etc. Every work Leader and supervisor concern must be very careful when deal with hazardous activity work, because simple or silly mistake done will result in high consequences. There are six items under the Hazardous activity section. Those are the handling hazardous chemical with the error probability is 0.8472, lifting work activity is 0.8812, gas testing failure is 0.1149, electrical or mechanical work activity is 0.1527, replacement of structural or piping is 0.1877. The total probability failure is 2.4610E-03.

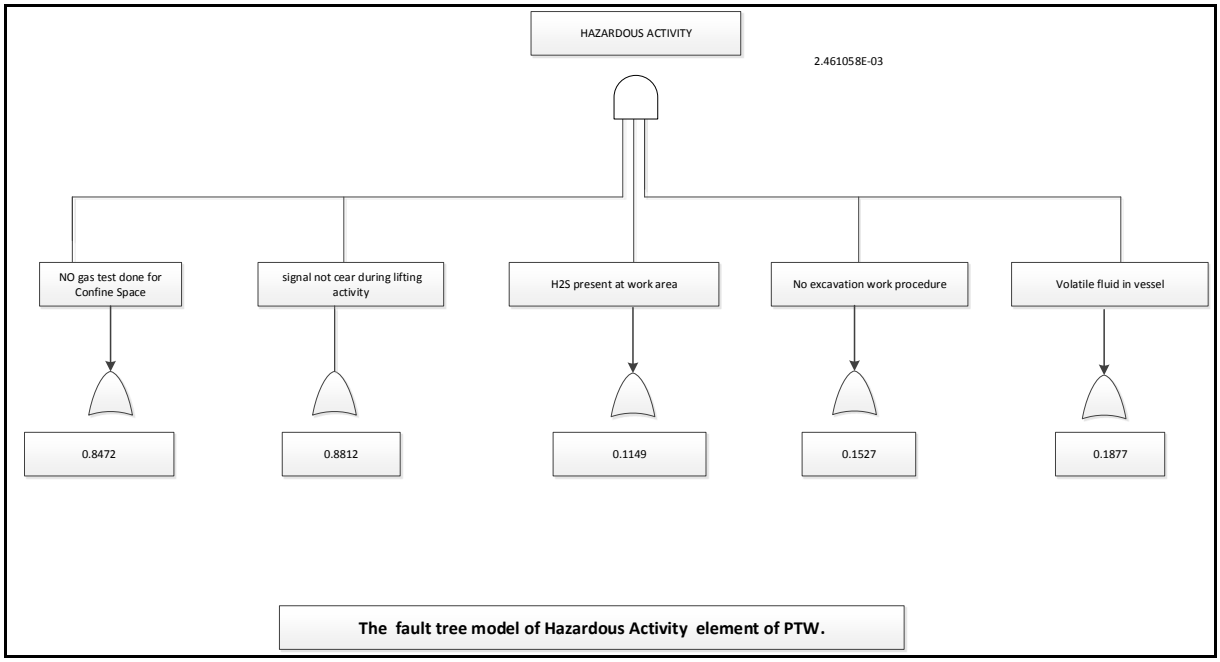

Figure 2. FTA for Hazardous Activity element

3.3 Worksite Inspection Element Failure

This is the third element of Permit To Work and has the 10 questionnaires items under this construct element. The Work leader and the area owner must be very diligent and carefully when fill-up this section. They are must performed thoroughly the area check before the particular PTW can be approved .The main item that must to check , but not limited to check such as scaffolding work, area free from combustible material, must do proper equipment isolation i.e. Lock Out and Tag Out, blinding or spading the equipment or vessel. If this barrier failed to check properly, the accident will happened. The used the FTA to calculate the error probability on each of items of each sub element. Error probability of failure to checking worksite is 0.6946, scaffolding error is 0.8668, failure to check area from H2S or mercury is 0.6996, failure to do Lock Out Tag Out is 0.1679, Blinding and spading failure is 0.1793, Failure to do N_2 purging is 0.27596, failure to install temporary sign and barricade is 0.18707, gas testing failure is 0.19924 and failure to do housekeeping is 0.15710. The total probability failure is 1.80821E-03.

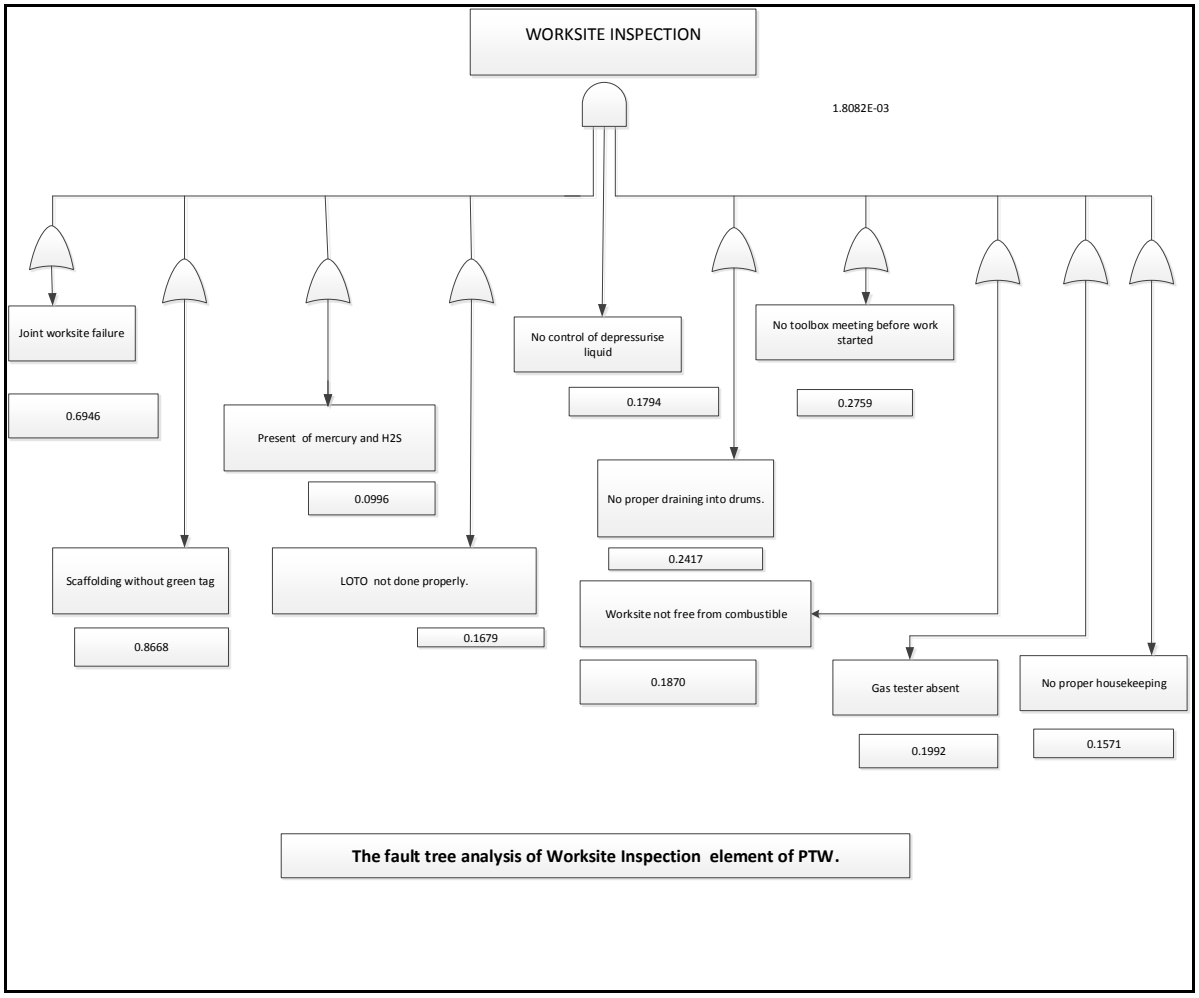

Figure 3. FTA for Worksite Inspection Element

3.4 Supporting Document Element Failure

Supporting document is the fourth element of PTW Accident model. This element is very important in supporting the PTW approval. All the document such as Job Hazard Analysis (JHA), Isolation certificate(Lock Out Tag Out) (LoTo), By pass certificate, Inspection certificate such s crane or vehicle inspection are attached together with PTW submission which are verifying that all the necessary equipment are fully isolated and secured to people to work on. For example the isolation job and Lock Out Tag Out (LoTo) must be done prior to approval of PTW and the isolation are done on equipment on site. Therefore in order to prevent any accident before it happen the focuses on all possible sources that is expecting to be existed in the plant area. The failure to comply with the supporting document will cause an accident with error probability for not attaching JHA is 0.1959, no vehicle inspection is 0.1954, failure to do risk assessment is 0.1374, physical isolation failure is 0.2222, failure to do switching bypass before do the job is 0.2233 and failure to performed gas testing is 0.1974. The total probability failure is 1.1695E-03.

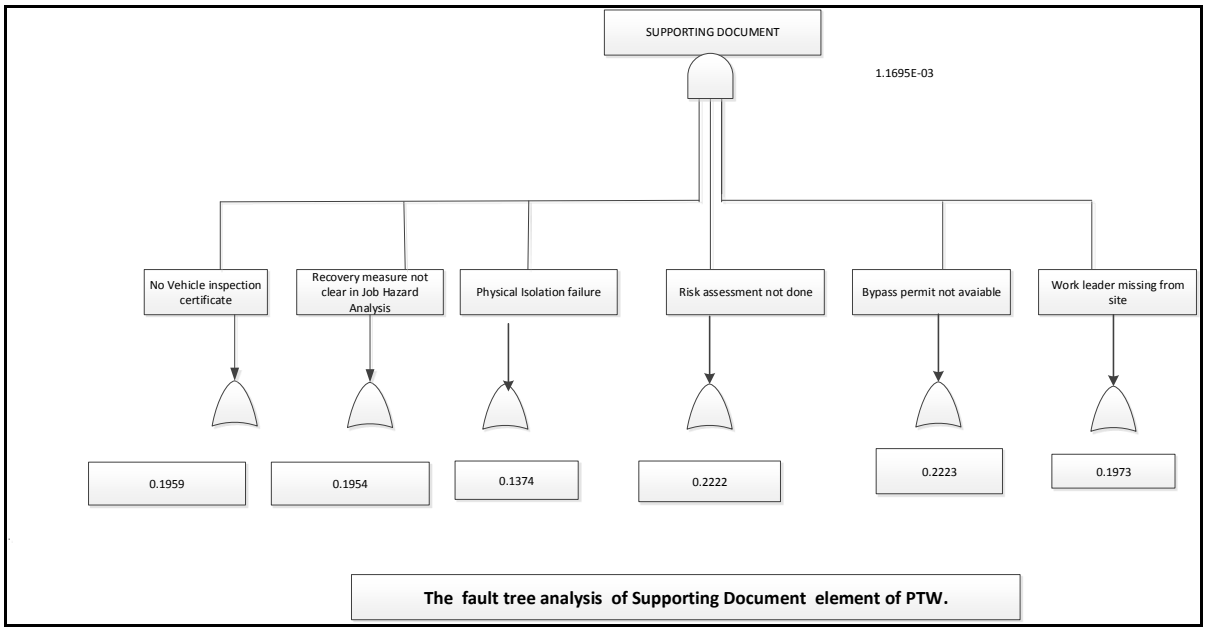

Figure 4. FTA for Supporting Document Element

3.5 Close Out Element Failure

This is the last element and last layer of protection in PTW. This element is to ensure all the items being check must to ensure permit user or work leader do housekeeping, proper handover if working on shift, ensure the area owner checking worksite after job completed before the permit being close out and sign off by Approval Party. Failure to do so will create error probability for housekeeping is 0.18143, handover failure is 0.15710, failure to do site checking is 0.15711 and failure to get job completion signature is 0.1036. At the end the total error probability is 5.2515E-08.

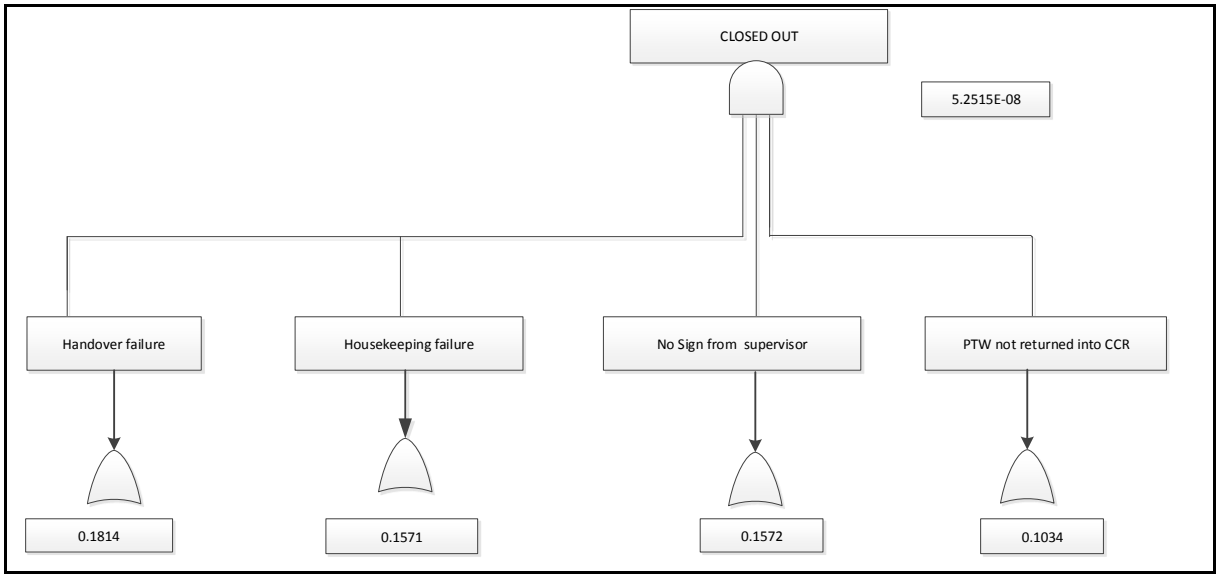

Figure 5. FTA for Close Out Element

4. Discussion

The whole Fault Tree Analysis for all PTW elements is shown in Figure 6 and results for comparison of SEM and FTA result is shown in Table 2 below:

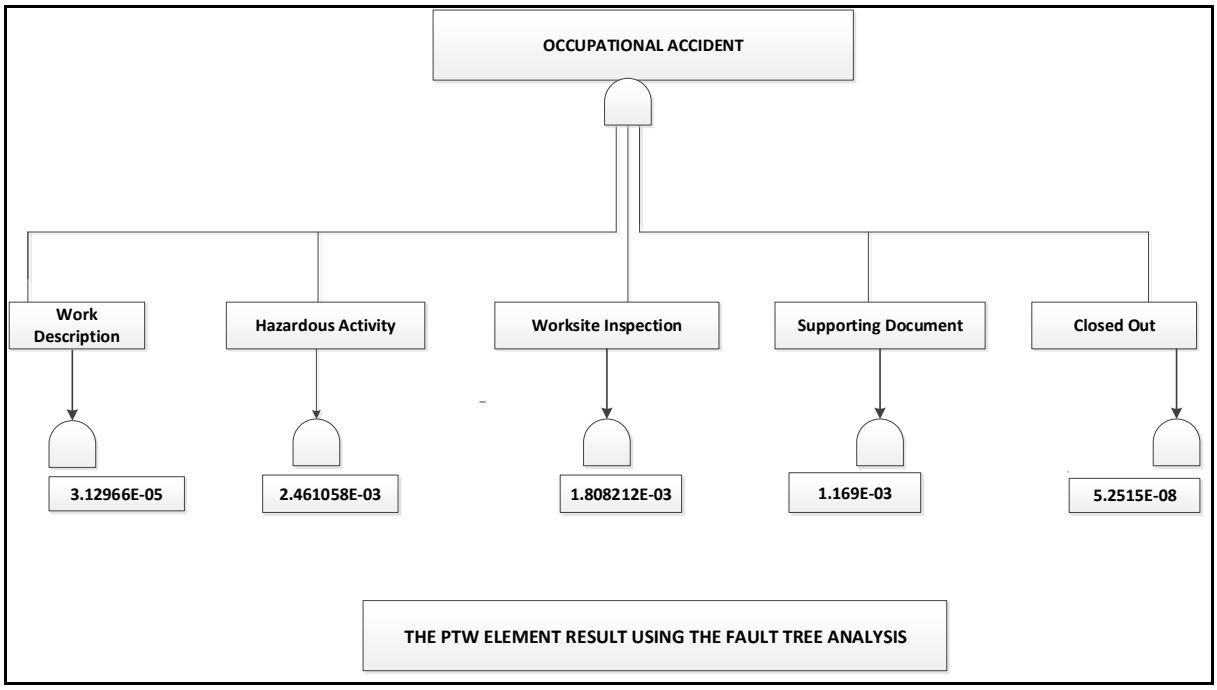

Figure 6. PTW Elements construct of FTA Analysis

The Permit To Work element results that has been performed by using Structural Equation Model (SEM) earlier that can be compared and found that from both results, its produced the same ranking with the Hazardous Activity is the main cause of the occupational accident. Even though the researcher used two different approaches either SEM or Fault Tree Analysis (FTA), both method still produced the same result and confirmed that the main cause of occupational accident occurring at site is Hazardous Activity and followed by other PTW element such as Worksite Inspection, Supporting Document, Work Description and Close Out.(refer to Table 4.1 below).

Table 2. Result SEM and FTA

No.	PTW Element	Result SEM	FTA Result	Rank
1	Hazardous Activity	0.56	2.4610 E-03	1
2	Worksite Inspection	0.32	1.8082 E-03	2
3	Supporting Document	0.22	1.1695 E-03	3
4	Work Description	0.16	3.1296 E-05	4
5	Close Out	0.05	5.2515 E-08	5

5. Conclusion

The depth study of an assessment Permit to Work element failure has been done earlier in Paper 1 using Structural Equation Model (SEM) analysis and the verification result was performed using the Fault Tree Analysis (FTA). The FTA results show the same rank with the SEM result i.e. Hazardous Activity is the main cause of occupational accident. From the result it was confirmed that the SEM results is correct and being proved and verified with FTA result and it meet the objective of the study.

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