The permit to work in relation with occupational accident at Petrochemical Plant.

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Abstract. Permit To Work is an official document used as a means of communication, control and managing of work activities to prevent accident at the Petrochemical Plant. But in many cases the Permit To Work has failed in its roles to control work activities which causes the occupational accident in the plant. Because of that this study was conducted to assess the Permit To Work in occupational accident occurred in the Petrochemical Plant. This study was conducted by distributing 260 survey questionnaire to Work-leader of various contractor company that work in the Plant. The data was analysed using the Exploratory Factor Analysis (EFA), Confirmatory Factor Analysis (CFA) to confirm the five Permit To Work elements construct. The Structural Equation Model was performed to identify most significant element related to failure of Permit To Work, and it was found that the hazardous activity and worksite inspection are the main element contributed to occupational accident in the Petrochemical Plant. The result of all the study has indicated that the Permit To Work and their element play important roles and it must be fully comply in every Permit To Work Process for work that need to be done in the Petrochemical Plant to ensure no accident occurred at Petrochemical Plant.

This is Part 1 of two paper, focusing on PTW Assessment. Part 2 deal with PTW Accident Model, PTW in Bow Tie, Predictive Modelling and Case Study.

Keywords: Assessment, EFA, CFA, SEM, AMOS graphic, FTA, Bow Tie and PTW Accident Model.

1. Introduction.

Permit to Work (PTW) is a document or official certificate used to manage and control of all work activities which is considered hazardous in Petrochemical Plant. [1]. It authorizes to carry out the work in the plant with all safety precaution in place, prevent them from all the possible hazards and the workers are performed the job safely. All the activities in Petrochemical Plant supposed to control by safe system of work i.e. controlled by Permit To Work [2]. The need of system of work is a must to ensure all the activities are carried out safely. [3] However, this Permit To Work fails to play its effective role in controlling and preventing frequent accidents occurring within the plant. Due to major accidents occurring in Piper Alpha and in some other plants it related to the Permit To Work failure in controlling all plant activity, researchers are trying to find which the PTW elements was failed in controlling the occupational accident in the Petrochemical Plant. The assessment of the Permit To Work with Occupational Accident will be done using the Exploratory Factor Analysis, Confirmatory Factor
Analysis and by Structural Equation Model and Amos graphic of the PTW on the occupational accident which involving the PTW element failure.

2.2 Hazards in Petrochemical Industry

The Oil and Gas Industry had been started in Malaysia at early seventies [4] The Oil Terminal are received the stored the hydrocarbon product such as crude oil and associated gas before it can be exported to other location but the Petrochemical Industry or the Petrochemical Plant is one of the most important economic forces on a global or local scale, process the hydrocarbon gas into wide range of product, such as automotive, agriculture and medicine [5]. The Petrochemical Plant has known as one of the hazardous workplace environment. The hazards at Petrochemical Plant has expose to the workers and must identified and corrected to prevent the accident. The Plant Management has urges the Contractor to aware about hazard, risk and accident at workplace and around them.

The emergence of any kind of hazard detected is in line with the rapid development in the industry including in the Petrochemical Plant. The hazard could be from process hazard, occupational hazard or external hazard [6]. As per Rathnayaka et.al stated in System Hazard Identification, Prediction and Prevention (SHIPP) the process hazard can cause the process accident, the occupational hazard can cause the occupational accident and so on. The accidents that occurs in the industry gives the impact to the individual with different severity such as non-fatal i.e. illness, injury and fatal or death to the people [7]. Because of the repetition occurrences of the accidents. The problem has been given serious attention by the many parties to look what are the cause of the accident. The researcher look more on occupational hazard and occupational accident and other caused of an accident that i.e. from the Permit To Work element failure. The example of the occupational hazard such as slip trip and fall, working at height, loud noise, vibration, unguarded machinery which can cause the occupational accident such as injury or death while performing work. From the accident report and research paper was mentioned about the combination of many factor such as hazard, poor maintenance and safety system including the deficiency of the Permit To Work was one of the reason for the accident to happened. As per [8] the Permit To Work was failed and did not ensure proper communication at the installation in the Piper Alpha Tragedy. The corrective measure must be taken to ensure Petrochemical Plant to become safer workplace by illuminating all the hazard and must be done at all time through the safety program and safety campaign such Unsafe Act Unsafe Condition and Or Confine Space Campaign.. The safety awareness campaign at Petrochemical should be the done continuously at all time to worker awareness and for occupational accident prevention at the plant.

2.3 Correlation between PTW and occupational safety and hazard

One of the finding from the HSE study of incidents in the workplace reveals that some of the accident was related to the maintenance-related work which involved the PTW system failure, where
the PTW system was inadequate to control the work. The PTW is to placing safeguard between personnel and known hazards which might be present. One of a result of the HSE investigation study it reveals that the PTW system needs to improve with every party at the Plant has one copy of PTW of that particular job that need to be done. Other example of the Oil rig accidents is the Piper Alpha Accident. The accident was occurred in 1988 which killed 167 workers off the coast of Aberdeen is the world’s deadliest ever oil rig accident. The finding after the incident has indicated that the failure of PTW system for example, related to shift handover, isolation and hazard recognition of the facility. According to (Mazlina Zaira & Hadikusumo (2017) [9], states that The fatality at workplace in the construction industry are high compared to other industry and one of the reason is the technical intervention was not done especially in Safety Permit in which the people doesn’t not comply with PTW requirement. In this case the PTW is one of the technical system and need to do intervene for any misconduct of PTW. The maintenance related work accident in Chemical Industry occurred in UK Chemical industry are contributed about 30% (thirty percent ) for the most related accident due to the Permit To Work system management failure as the UK Health and Safety Study(2017) i.e. Failure to implement effective Permit To Work System[10]. The important of having PTW in Oil and Gas Industry is for accident prevention especially involving major hazard in major installation such as the installation of new piping or equipment where proper work permit and risk assessment procedure should be done correctly with all around hazard must be registered before job executed to prevent such accident. Most common failure in PTW system is the failure in isolation process and procedure, not suitable and sufficient to identify the risk. This research was conducted looks in the Permit To Work (PTW) element failure in relation with the occupational accidents at Petrochemical Plant. As per Abdulhamid et.al 2008 [11] mentioned there are few causes of occupational accident in construction industry. Those causes are hazard at worksite, worker negligence, failure to follow work procedure, failure safety devices on equipment poor site management, harsh work condition, low skill and knowledge of workers, communication failure, low attitude of workers about safety, poor site management, harsh work condition and failure in managing Permit To Work (PTW)

The researcher focus on the non-compliance elements in PTW at onshore Petrochemical Plant which in many cases can contribute to incident or fatality, even though much precaution has been done to prevent such incident. The PTW system together with risk assessment is to reduce the levels of risk to low as reasonably practicable (ALARP) before we can allow workers work on equipment or systems. One example on how occupational accident was occurred in 2016 when of the contractor staff was collapsed immediately upon entry of vessel of confined space. He was pronounce dead upon arrival at the clinic. Upon investigation it was found no risk assessment including Job Hazard Analysis (JHA) was conducted, used the paint was not identified as a hazard with no Safety Data Sheet (SDS), lack of control of the Permit To Work for that activity. Furthermore Joint site visit was not conducted, hence no verification conducted on confined space isolation points, ventilation setup and readiness of emergency rescue equipment airline. For this research work, the researcher looks on each of the PTW element and
their impact to occupational accident. Even though PTW has been approved in every job in the Petrochemical Plant, but there is still found non-compliance elements whenever when the operators conducting the Permit To Work audit. Because of non-compliance to these element it will contribute to the accidents. The non-compliance to the PTW become issue and must be corrected to prevent an accident.

There are requirement to Permit Applicants or Work Leader to comply whenever applying the Permit To Work for the job and fulfil with element during PTW process. Those element used for this study are Work Description, Hazardous activities, Worksite preparation, Supporting Document and Close Out. The PTW elements, it is important to fulfil every requirement of PTW element and must be followed strictly when applying PTW, so that all jobs can be performed and safe without any accident. These Element are being designed and used for this study.

2.6. Permit To Work elements

There are five (5) PTW elements used in this study. These elements is the renewal from the last paper [12]. The new Permit To Work elements that being used in Petrochemical Plant as below:

i. Work Description
   The Permit Applicant or Work Leader should fill up this first section by giving all necessary info regard to their company, work area, description of work that need to be done in detail.

ii. Hazardous Activity
    Under this element, the Permit Applicant or Work Leader must fill all the hazardous activity related the job that is going to be done such as hydrocarbon liquid/gas, pressure test, working at height, scaffolding, or working in confine space.

iii. Worksite Inspection
    Under this element, the Permit Applicant or Work Leader must fill up the required information or anything that required to be prepare for worksite preparation such as positive removal of energy, equipment drained or depressurized equipment blind /spade, worksite free of combustibles, gas test or purging.

iv. Supporting document
    Permit Applicant or Work Leader must attached with JHA and others work certificate. The work certificate will be attached whenever any electrical isolation, physical isolation, confined space being done. If any equipment or switch required bypass, then the bypass certificate will be issued. Whenever all the element is being marked, attached all the necessary JHA form and Work Isolation Certificate, then only can being sent to Supervisor for approval.

v. Close Out
    Under this section the work leader need to close the PTW after the job completed. Prior to close out, proper housekeeping and handover for work status also being done and updated.

3. Methodology.
The methodology used are based on the Conceptual Framework of the study as per Figure 3.0 below. The Conceptual framework describe the relationship between specific variable in the study. It is a structure indicating the way of study should be build and show the route of a study. It also outlined the input and output of the whole research investigation, shown the route of a sequence process and provide the picture for the solution of a problem area between both side of construct and variable of the study i.e. Independent Variable (IV), i.e. PTW and observed variable i.e. Dependent Variable (DV), i.e. Occupational Accident.

![Figure 3.1 Research Framework](image-url)

**Figure 3.1 Research Framework.**
The methodology using quantitative approach divided in three phase for ease of the study (refer to Figure 3.1). This methodology will cover Hazard identification and analysis, process and occupational accident (Phase 1), questionnaire design using Delphi Technique (Phase 2). Discussion on data analysis and assessment using Exploratory Factor Analysis (EFA), Confirmatory Factor Analysis (CFA), and Structural Equation Model (SEM) (Phase 3). The results from SEM being analysis and compared with Fault Tree Analysis (FTA). The research continue with the Permit To Work Accident Model and placing the Permit To Work in Bow Tie predictive modelling and validation with case study. (Phase 3, Part 2)

3.1 Pilot and actual study

The pilot test was conducted by distributing 100 questionnaires survey into the Petrochemical Plant work leader and workers who are experience in handling PTW. The questionnaire was reviewed by Safety Expert using the Delphi Technique. After the pilot test, the researcher performed Exploratory Factor Analysis (EFA). The actual study was done by distributed another questionnaire survey to 260 workers for Confirmatory Factor Analysis (CFA). These two factor analysis was performed prior the Structural Equation Model (SEM) and was discussed in detailed on each respective paper.

3.2 The Pooled Measurement Model for all Constructs

The CFA can be performed for pooled measurement model. It is produced from more than one construct. It must meet all the criteria of unidimensionality, validity and reliability of a construct. The pooled measurement shown in Figure 3.4.
3.3 Structural Equation Model (SEM)

Structural equation modelling is used to formulate a relationship between a set of variables and factors and measures the existing casual relationships on a linear equation model after the development of measurement model, pooled model and structural models. The theorized link of measurement model for independent variable and dependant variable construct is called the structural model.

SEM was used to test the effects of variables and the relationship between the variables or construct together with their respective item in the model and analyse them simultaneously.[12] (Hair et al. (2010). Structural Equation Modelling (SEM) is performed after all the validity requirements construct. The SEM will satisfies the best fit to answer the research questions and hypothesis of the research validity, convergence validity and discriminant validity and Composite Reliability are achieved.(Gerbing & Anderson, 1985) [13]

4.0: Result

The result of all the Permit To Work (PTW) constructs were incorporated into the structured model of the Structured Equation Modelling (SEM) of the AMOS text output. The validation of relationships between constructs are the standardized regression and unstandardized regression estimate. The graphical output i.e. the standard regression value between the constructs showing the regular regression weight values as in Figure 4.1, while the Figure 4.2 shows the unstandardized regression value is a original unit as a result of the SEM procedure.
Figure 4.1: SEM Findings Shows the Standardize Regression Value between Constructs

a) As per Figure 4.1, the results from the SEM findings, the Standard Regression Coefficient or Coefficient of Determination ($R^2$) is $0.80$. Its means that, the Permit To Work elements (see arrows) i.e. the Work Description (WD), Hazardous Activity (HA), Worksite Inspection (WI), Supporting Document (SD) and Closed Out (CO) contributed 80 percent to the Occupational Accident (OA) at Petrochemical Plant. Other factors influence to the occupational accident is about 20 percent. From this equation, the main factor effect is Hazardous Activity (HA) and Worksite Inspection (WI) because the high value compared to the cofounding effect is Supporting Document (SD), Work Description (WD) and Close out (CO).

i. The Standard Regression Coefficient for Hazardous Activity element toward occupational accident is 0.56, meaning that if a unit of hazardous activity increases by one unit, the occupational accident unit will increase by 0.56 of standard deviation.

ii. Worksite Inspection is 0.32, The Standard Regression Coefficient for Worksite inspection element toward the occupational accident is 0.32, meaning that if a worksite inspection increases by one unit, the occupational accident unit will increase by 0.32 of standard deviation.

iii. Supporting document is 0.22. The Standard Regression Coefficient for supporting document element toward the occupational accident is 0.22, meaning that if a supporting
document increases by one unit, the occupational accident unit will increase by 0.22 of standard deviation

iv. Work Description is 0.16. The Standard Regression Coefficient for work description element toward the occupational accident is 0.16, meaning that if a work description increases by one unit, the occupational accident unit will increase by 0.16 of standard deviation.

v. Close Out is 0.05. The Standard Regression Coefficient for close out element toward the occupational accident is 0.05, meaning that if a Close Out increases by one unit, the occupational accident unit will increase by 0.05 of standard deviation.

b) The correlation between the construct i.e the strength of the relationship between construct can be seen by the double sided arrow in figure 4.2 also. The Table 4.10 (Pearson Correlation Table) can be used for reference to see the strength or weaknesses of relationship between those construct:

i. The correlation between Hazardous Activity(HA) and Work Description is 0.01(very weak)

ii. The correlation between Worksite Inspection(WI) and Work Description(WD) is 0.34.(moderate)

iii. The correlation between Worksite Inspection(WI) and Hazardous Activity(HA) is 0.03(weak)

iv. The correlation between Supporting Document (SD) and Work Description(WD) is 0.01(weak)

v. The correlation between Supporting Document (SD) and Hazardous Activity (HA) is 0.82(strong)

vi. The correlation between Supporting Document (SD) and Worksite Inspection (WI) is 0.29(moderate)

vii. The correlation between Close Out(CO) and Work Description(WD) is -0.05(very weak),

viii. The correlation between Close Out (CO) and Hazardous Activity( HA) is 0.17(weak)

ix. The correlation between Close Out (CO and Worksite Inspection (WIP is -0.01(weak)

x. The correlation between and Close Out(CO )and Supporting Document (SD) is 0.23(weak).
Table 4.10: Pearson Correlation table

| Strength of relationship | Coefficient of Correlation r Value |
|--------------------------|------------------------------------|
| Strong                   | -1.0 to -0.5 or 1.0 to 0.5         |
| Moderate                 | -0.5 to -0.3 or 0.3 to 0.5         |
| Weak                     | -0.3 to -0.1 or 0.1 to 0.3         |
| Very Weak                | -0.1 to 0.1                        |

c) SEM findings the Unstandardized Regression Value between Constructs

![Figure 4.2: SEM Findings Shows the Unstandardized Regression Value between Constructs](image)

ii. **Multiple Regression equation in impact calculation.**

The regression is used to predict one variable based on another variable. Because of that the simple regression was used to identify the effect of one unit change in independent variable to dependent variable. Permit to Work (X₁) and Occupational Accident (Y) are two interconnected observe variables, X is the independent variables and Y is dependent variables, the relationship between these two variables for estimating the causal effect of X₁ on Y and to test the hypothesis to prove it significance. The regression will be used to see the impact of the PTW element with
multiple indicator to occupational accident. Initially the relationship between variable \(X\) and \(Y\) is represent by the simple regression equation i.e. \(Y = \beta X + e_1\). The researcher used the combination of simple regression to produced multiple Regression and analyse the model based on this formula as figure 4.4 below.

\[
Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + e_1
\]

\[
Y = X_1 \beta_1 + X_2 \beta_2 + X_3 \beta_3 + X_4 \beta_4 + X_5 \beta_5 + e
\]

\[
OA = HA + WI + SD + WD + CO + e
\]

\[
OA = 3.50HA + 2.80WI + 1.30SD + 0.60WD + 0.09CO + 0.32 \text{ (Note: Error value is 0.32 from the R1 in Figure 4.2.)}
\]
The unstandardized SEM result in bar graph as illustrated in bar graph in figure 4.4 below.

**Figure 4.4: Unstandardized regression result in bar graph**

![Bar graph showing regression results](image)

\[ \text{OA} = 3.50\text{HA} + 2.80\text{WI} + 1.30\text{SD} + 0.60\text{WD} + 0.09\text{CO} + 0.32 \]

### 4.1 Impact analysis between constructs

The researchers performed the hypothesis testing to answer the research question and hypothesis of this study.

| Constructs                  | Estim (regression value) | S.E. | C.R.   | P       | Result   |
|-----------------------------|--------------------------|------|--------|---------|----------|
| Occupational_Accident       | Hazardous Activity       | 3.453| 0.656  | 18.377  | 0.001    | significant |
| Occupational_Accident       | Worksite_Inspection      | 2.804| 0.770  | 9.947   | 0.001    | significant  |
| Occupational_Accident       | Supporting Document      | 1.301| 0.372  | 12.007  | 0.001    | significant |
| Occupational_Accident       | Work Description         | 0.602| 0.306  | 6.397   | 0.001    | significant |
Table 4.3: Hypothesis testing of the PTW element

| Constructs | Constructs | Estimate value | S.E. | C.R. | p   | Result |
|------------|------------|----------------|------|------|-----|--------|
| Occupational_Accident | Close out | 0.094          | 0.130| 2.487| 0.001| Significant |

From the all the hypothesis done, it found that all the PTW element has given significant impact to occupational accident (Table 4.1 and 4.2).

5.0 Discussion

The study aims to identify PTW's relationships and impacts that comprise five elements on occupational accident. This study uses quantitative approaches and survey methods to obtain feedback for the study data. While the study population consists of Work Leader in the Oil and Gas sector at several Petrochemical plants in Kerteh, Terengganu Industrial Area. The questionnaire pattern is adapted from the Structural Equation Model of the safety intervention study in Construction Industry (Mazlina Zaira (20170) [14]. The analysis of the data was carried out by using descriptive statistics, inference and advanced multivariate analysis of Structural Equation Modelling (SEM). Descriptive analysis is used to obtain the frequency, while mean score and standard deviation are used to analyse hazardous activity, worksite inspection, supporting document, work description and close out as the PTW element itself. Inference analysis is used to analyse all hypotheses to describe the effectiveness of the hazardous activity.
construct, worksite inspection, supporting document, work description and close out of occupational accidents.

From the study and hypothesis testing researchers have proven that each of the PTW elements has a significant impact on occupational accidents where hazardous activity has become the main element that affects occupational accident with the value of 0.56 (Refer to Figure 4.1. The hazardous activity must be properly monitor and look after it very carefully to avoid the occupational accidents such as vessel cleaning in confine space, lifting spool or any mechanical maintenance job. One example of the accident was the finding of the Confined Space Incident when the paint was not specify in PTW as a hazard and no risk assessment was done. The accident in hazardous activity contribute about thirty percent of the occupational accident in Petrochemical Plant which is this finding is in line with the UK HSE Safety and Health report which states that hazardous work is indeed causing the accident. UK HSE Safety and health report issued (2017) and Illife (1999).

Worksite Inspection is the second highest element i.e. 0.32 which is the second ranking which caused the occupational accident. Failure to do worksite inspection or prepare the worksite properly and contributed to Occupational Accident. (Marhavilas & Koulouriotis, 2008). Worksite needs to be checked before PTW is approved to be free from any hazard that can contributes to the accident. Joint site visit is an important part of PTW to identify hazard and precaution at site. Many lives were lost because the site visit were not conducted properly. Examples of an accident occurred due to the untidy, and dirty worksite that had not been cleaned before welding work can be done. The negligence identified the source of danger in the worksite to attract hazards such as fire during welding work. Fire watch should be given the task of controlling the welding flares. And the worksite needs to be updated after the work is done. Ensure worksite and equipment left in safe state. Ensure site is ready for reinstatement and give back the worksite clear to area owner in good shape after job completed.[15] (Noroozi, Khazad, Khan, Mackinnon, & Abbassi, 2013)(Noroozi et al., 2013).

The supporting document is in third rank with the value is 0.22 in Figure 4.1. The very important supporting document during PTW application is Job Hazard Analysis (JHA), electrical isolation certificate or physical isolation certificate. Supporting document must be attached in the Permit to Work process. Without supporting document Permit To Work cannot be approved by management. In case of accident happened the supporting documents can be material evidence with the authorities and also in case of litigation in court. (Candiah, 2005)[16]. The compliance of all the supporting document factor gives an impact on the successful implementation of PTW Management System at workplace.

The forth element in the ranking is work description with the value of 0.16. The work description is a statement of the work to be carried out within the Plant. This statement must be accurate and easy to understand to the management and the operators on duty to avoid misunderstanding about the equipment and the area where the work that to be done. There is a mistake in filling the item in this section in work description section. The inadequate work description in Permit To Work such as not specify equipment
or machine and location required for the task. It can cause confusion to other party which can lead to unexpected accidents.

Close out with the value of 0.05 is the last element in Permit to Work. Mistakes and disincentives in closing such permits do not make proper handover and housekeeping work invites the accident. Proper handover and proper housekeeping need to be done so that the process in the plant are not interrupted and restore the clean and orderly workplace avoids the reigniting element of the fire source in a welding work in the plant. There has been an accident due to negligence in the closure of this work permit and the work leader must ensure that PTW is closed properly before leaving the work area.

From the result of the study also, the main factor effect is the Hazardous Activity (HA) and Worksite Inspection (WI) compared with compounding effect i.e. Supporting Document (SD), Work Description (WD) and Close Out (CO). From the SEM Amos result also indicted that the Occupational Accident has an effect to Asset is about 94 percent, Human effect is about 89 percent and the environment effect is about 39 percent. The results from SEM, generally all the PTW element gives significant impact to occupational accident. The SEM result are being compared with the results of Faults Tree Analysis (FTA). The discussion on Fault Tree Analysis will be in Part 2 of this study.

6.0 Conclusion

The depth study about the Permit to Work has been planned and performed in sequence step by step in order to fulfill and answered all the objective and research question. The very detailed questionnaire survey using the expert review and the PTW Element assessment, has been done in orderly manner. Therefore, the workers should not take it easy with PTW. All must kept in mind and remember that, don’t think Permit To Work as a paperwork. It’s the barrier for accident prevention. Don’t let the PTW became major finding each year whenever Occupational Accident occurred at Petrochemical Plant.

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