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ORIGINAL ARTICLE

Fault Creator Cases Analysis Based on Bayesian Method in Current Permit to Work System to Optimize the Protection Layers and Risk Management, During Commissioning and Start-up Phases of Gas Refinery Plant

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ABSTRACT

Accident statistics indicate that the majority of accidents at four categories of human, environment, equipment, and reputation of a community have mainly occurred in the process industries. Amongst them, the Oil and Gas industries have a significant portion, as these industries handle large quantities of flammable, toxic chemicals, and exposure to the high potential of serious accidents. Having considered these issues, it is essential to execute an in place safe system of work in such industries. Permit to work system (PTWS) is one of the most important and effective key of HSE-MS sub-systems, which has a significant role in identifying, predicting, controlling, and eliminating hazards of activities and probable accidents at workplaces. As a question for this research, it is being used in the oil and gas industry. Currently used PTWS method at gas refineries in Pars Special Economic Energy Zone (PSEEZ) is a paper-based management system document, based on the statistical results obtained using the experiences of trustees and experts, which intrinsically contains some defects and deficiencies; consequently it could not provide sufficient and effective barriers. These inherent PTWS errors and faults as the data-based permit to work system (D.B.P.T.W) are leading the operating system to different types of accidents, and finally system failures and catastrophic disasters. Therefore, in this study Bayesian theory was applied for the conditional probability of fault creator cases (FCCs) of PTWS assessment. Fault creator cases analysis in permit to work system with changes in the current PTWS were used (Current Permit to Work, C.P.T.W) in gas refineries by logical management. So that the use of this new method based on historical and interconnected and multi-faceted fault factors communication and also disconformity/capability for immediate and simultaneous informing and discovering on the relevant system components and also according to a Bayesian analysis on seven important and critical variables for both CPTWS and DPTW.S for pessimist and optimist statuses may improve the protection safety layers and it is possible to decease and finally eliminate accidents as low as reasonably practicable (ALARP) level at gas refinery plants.

KEYWORDS: *Permit to Work System, Inherent, Bayesian, ALARP*

INTRODUCTION

Accident data demonstrated that the majority of human, environment, and equipment and reputation accidents have mainly industrial causes and reasons, and among industries, the oil and gas industry especially, the initial phase of the chemical design process accounts for having more accidents [1]. Since these industries handle large quantities of flammable and toxic materials, the potential of severe accidents is high, so it is vital to have safe systems of work in place. One of the essential parts of safety management systems is the control of work (COW) procedure. COW is made up of several parts including permit to work system (PTWS), hazard identification (HI) [2], risk assessment (RA), and isolation management (IM) [3]. PTWS has a long history of association with safety management. As a definition, PTWS is a formal written system used to control certain types of work, usually maintenance, that are recognized as potentially hazardous. In a simple word, the term 'permit-to-work' or 'permit' refers to the certificate that is used as part of the general system of work. The permit to work (P.T.W) is a written document which states precisely to certain people/workers to carry out specific work at a limited time. PTWS is also set out the hazards associated with the work and the precautions to be taken [4]. Accordingly, written documents and a series of regulations in PTW systems unify both keeping safe methods of working [5]. PTWS, as the core element of the COW along with RA and IM, are key contributors to the safe execution of jobs and enable as low as reasonably practicable (ALARP) reduction of unsafe/hazardous activities in non-trivial work environments. A generic PTWS tries to meet the following three main objectives:

Firstly, to ensure that sufficient consideration has been given to all aspects of hazards.

Secondly, to confirm that sufficient precautions have been considered and where possible taken before the permit to work is given.

Thirdly, to formalize and improve communications between all parties involved in the work [6-7]. Hence PTWS is a holistic and integrated system that provides a standardized approach inclusive of all the aspects of the operation, namely permit process, guiding documents, job risk assessment (JRA), toolbox talk (TBT), barrier management, management of change [8].

On 6th July 1988, 167 men died because of an explosion and fire on board of the Piper Alpha platform in the UK region of the North Sea. Lord Cullen, who was in charge of investigating the cause of the disaster, issued his report in December 1990 and concluded that one of the primary causes of this disaster was a failure in a safety management systems key, that is, the PTWS [9]. In 1987 The Chemical Manufacturing National Interest Group (NIG) and the Accident Prevention Advisory Unit (APAU) along with HSE, published a report titled Dangerous Maintenance, which investigated the statics of unsafe incidents in the chemical industry. They stated that 30% of all reported incidents happened due to improper maintenance activities, in a way that, in 20% of this maintenance the PTWSs were implicated [10-11]. Moreover, hidden accidents and incidents costs caused by uncontrolled health, safety and environmental management were about 12 times higher than direct damages cost [12]. A computerized permit to works would have many advantages which may enhance permit systems reliability, performance, usability, and applicability. This permit to work form-filling may provide better experience for supervisors and managers to analyze work tasks any time from any location.

A computerized PTWS may prohibit to issue more than one permit for the same task and could remind workers for the nearby work in progress [10]. Up to now, very limited studies have been conducted regarding human error analysis in the PTW system. In the late 1980s, the occurrence of certain developments in the theory of human error led to the development of nuclear database in United States of America comprised of hardware failure data and some human error probability data. In this database in 1998, humans were categorized based on human error probability estimates by expert-judgments [13]. Kirwan et al. introduced computerized operator reliability and error database (CORE-DATA) which was a computerized human error database for human reliability support [14]. It was dissimilar to NUCLARR database which was constructed based on real observations of incidents or errors.

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In 1997, nuclear-power related HEPs created 110 out of 400 [14]. Iliffe et al. [10] developed a system linking computerized PTWs with an incident database. This system examines the nature of the job, equipment, and chemicals determined on the PTWS, and inform users with relevant incident reports without requiring explicit searches or further data. It was concluded that employing the proposed system makes PTWs far more effective [10]. Neill reported the benefits of employing the web-based, Hard Disk Sentinel Professional (HD Sentinel), electronic integrated safe system of work solution developed by Pyrotechnics' in a major integrated oil company which was operational in 20 offshore fields in North Sea [15]. This system unified PTWS and risk assessment activities and it was efficient method for supervisors to save time and be more efficient. The proposed approach provides a win-win situation, which yields benefits in cost reduction and safety performance improvement. Neill proposed that to reach a win-win situation, the system must be reliable and fast, and also effective risk assessment should be core to all work activity process, and the employee must be engaged in the process and communicated with frequently to create acceptance [15]. Qatar gas company issued about 36000 permit-to-work yearly in 2006 using electronic PTWS and expected to had enormous advantages in reducing conflicts between jobs, demanded time reduction, and safer work control [16].

Pars Special Economic Energy Zone (PSEEZ) established in 1998 to utilize oil and gas from South Pars/North Dome Gas-Condensate field and located in the Persian Gulf. In PSEEZ, HSE-MS created according ISO 14001, OHSAS 18002:2000, OGP (Oil and Gas Producers), and API Standard models and PTWS as one of the sub-systems of HSE-MS are fulfilled based on OGP permit to work procedure in PSEEZ. Gas refineries stand for high risk and hazardous workplaces. Considering 36000 PTWs per year, it is necessary to plan and execute active HSE-MS and it's subsystems to decease and finally eliminate accidents as low as reasonably practicable (ALARP) level at gas refinery plants.

This study was aimed to first determine disconformities and fault creator cases (FCCs) of currently used paper-based PTWS in PSEEZ then according to seven most effecting FCCs, a new electronic-based PTWS will be designed by introducing corrective actions and new protection layers in each 9 main parts of the currently used PTWS procedure. Besides, the procedure of the currently used paper-based PTWS and its disconformities FCCs will be presented, and then a semi-intelligent PTWS with the electronic database will be introduced by defining the structure of the electronic database and corrective actions (protection layers) to remove and correct disconformities and FCCs, and leading system to ALARP level.

MATERIALS AND METHODS

Currently used PTWS method at gas refineries in Pars Special Economic Energy Zone (PSEEZ) is a paper-based document management system and another suggested PTW is the data based permit to work system (D.B.P.T.W). Therefore, in this study fault creator cases analysis based on Bayesian method in current permit to works system have been used to optimize the protection layers and risk management as following steps:

- Selection of seven prominent FCCs of PTWS.
- Following FCC_S offered as a cause and disconformities.
- FCC_S capabilities at PPTWS analysis.
- Assess the consider barrier of FCC_S.
- Discuss the reliability of results.
- Characterize Bayesian methods for the conditional probability of FCCs and critical variables.
- Discuss Bayesian probability analysis results and reliability for PPTWS and DPTWS.
- Clarify the importance of these two permits to work methods to decrease accidents and effectively.

As mentioned in above steps, to execute risk assessment analysis, based on the obtained statistical results using the experiences of trustees and experts in this field, seven prominent FCCs of PTWS selected and considered as a sample. According to diagram 1, the following FCCs offered as causes and disconformities. These FCCs are the most important and critical functions of PTWS at commissioning and start-up phases of gas refinery plant (Table 1).

Table 1. FCCs Capabilities/Descriptions of PTWS at commissioning and start-up phases of gas refinery plant

FCCs Capabilities	Descriptions
A	Capability for Immediate and simultaneous informing the issued permit topics to all other areas A.I.Ps
B	Capability for Immediate and simultaneous informing the issued confined spaces permits to all other areas A.I.Ps
C	Capability for Immediate and simultaneous informing the issued HNF permits to all other areas A.I.Ps
D	Capability for Immediate and simultaneous discovering the involved peoples "signature counterfeit" or other illegal manufacturing at a permit
E	Capability for Immediate performing risk assessment for each issued permit topics by all area A.I.Ps
F	Capability for Immediate Access Record for Missed Permits
G	Capability for Immediate controlling the A.I.P Competency Based on Field and Area Wise

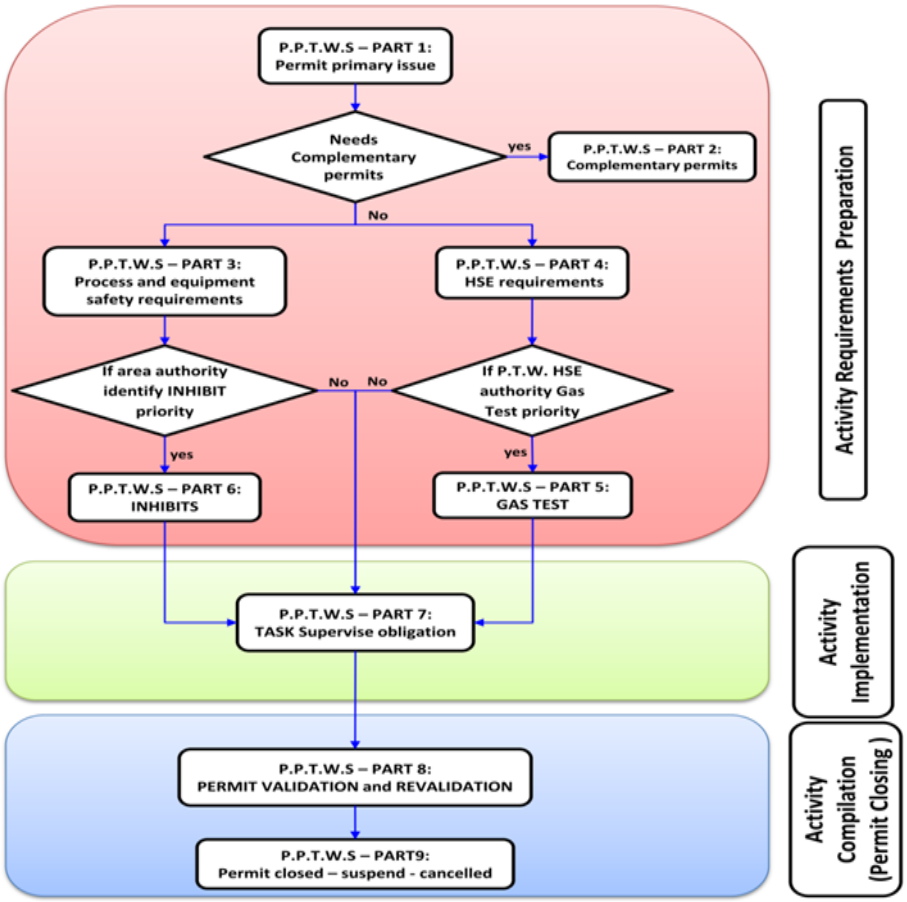

Fig. 1. Flow diagram of the currently used PPTWS at PSSEZ

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According to Figure 1 (risk analysis method), above mentioned capabilities (A,B,C,D,E,F,G) at P.P.T.W.S were zero or very weak and also considered barriers (1,2,3,4,5,6,7) were insufficient and ineffective. Therefore P.P.T.W.S was moved to failure and finally would result in accidents (human, environment, material) and thus had low reliability, which will be proved in this research by the BP method.

Bayesian theory for the conditional probability of FCCs:

Thomas Bayes determined first mathematical treatment of a non-trivial problem of Bayesian inference. Bayesian probability is an interpretation of the concept of probability, in which, the probability is interpreted as reasonable expectation representing a state of knowledge or as quantification of a personal belief [17].

Bayesian methods are characterized based on concepts and procedures as follows:

Random variables or more generally unknown quantities application, to model all sources of uncertainty in statistical models. This also includes uncertainty resulting from lack of information, While for the frequents a hypothesis is a proposition (which must be either true or false) so that the frequents probability of a hypothesis is either 0 or 1, in Bayesian statistics the probability that can be assigned to a hypothesis can also be in a range from 0 to 1 if the truth value is uncertain [17].

RESULT

The currently used paper-based PTWS in gas refinery plants at PSEEZ is specific to the commissioning and startup phases. In this study 23 FCCs (fault creator cases) were determined to design paper-based PTWS according to the permit related accident statistics at PSEEZ, expert's experiences, and previous studies finding as shown in Table 3 [18].

Following procedures have done to control and eliminate FCCs in PTWS:

1. Training and Meeting
2. More new personnel office permission
3. Keeping one of permits paper at the permit office for more guaranty
4. Area authority writes issued permits number in his notebook
5. All AIPs have verbal coordination (wireless) together
6. All issued permits recorded at permit office book and an excel file
7. Procedure updating

The above results showed that these protective layers are insufficient and ineffective so that the PTWS will lead to failures in four branches of human, environment, equipment, and reputation.
Hence, considering the following items;

- Presence of huge volume of dangerous chemicals gas-liquid-solid in zone
- Refineries vastness, interconnections, and closeness to the residential ports
- Presence of a great number of workforces (native and non-native) in this zone
- The strategic importance of environment issues (water-soil-air) of the zone on the national and international level
- Sustainable development indexes of the zone on national and international effects

It seems necessary to perform some effective corrections in both structural and executive perspectives of currently used paper-based PTWS, to minimize or eliminate accidents and human errors, and leading the system to ALARP.
Investigating and concentering on the performed PTWS reliability analyses and system FCCs, the following seven items were determined as the main core of errors:

1. Capability for Immediate and simultaneous informing the issued permit topics to all other areas AIPs
2. Capability for Immediate and simultaneous informing the issued confined spaces permits to all other areas AIPs
3. Capability for Immediate and simultaneous informing the issued HNF permits to all other areas AIPs
4. Capability for Immediate and simultaneous discovering the involved peoples "signature counterfeit" or other illegal manufacturing at the permit
5. Capability for Immediate performing risk assessment for each issued permit topics by all area AIPs

6. Capability for Immediate Access Record for Missed Permits
7. Capability for Immediate controlling the AIP Competency-based on-field and area wise

Therefore, at the following, a semi-intelligent PTWS with the electronic database is proposed to overcome the deficiencies of the currently used paper-based PTWS, and correct or eliminate the above mentioned FCCs. In the proposed new PTWS, the electronic database is divided into the following main parts.

- Electronically identification of all the involved and responsible persons at permits, to PTWS.
- Electronically definition of all areas of the refinery, to PTWS
- Electronically availability of risks assessments documents of the different activities, in PTWS
- Electronically definition all types of main permits (cold - hot - naked flame) in PTWS
- Electronically definition of complementary permits in PTWS

Corrective actions to create database based on PTWS nine main parts of PBPTWS have been explained in Table 4.

Table 3. Disconformities and FCCs of the currently used paper-based PTWS

No.	FCC	No.	FCC
1	Capability for Immediate and simultaneous informing the issued permit topics to all other area authorized involved personals (AIPs)	13	Capability for Immediate and simultaneous informing the issued confined spaces permits to all other areas AIPs
2	Capability for Immediate and simultaneous informing the issued HNF permits to all other areas AIPs	14	Capability for Immediate and simultaneous informing the permit-related emergency force cases to all other AIPs
3	Capability for Immediate and simultaneous smart controlling and monitoring active permits	15	Capability for Immediate and simultaneous informing the canceled permits to all other AIPs
4	Capability for Immediate controlling the A.I.P Competency Based on Field and Area Wise	16	Capability for Immediate Access Record for Missed Permits
5	capability for decreasing human resource and accordingly decreasing human errors	17	Capability for saving in the paper and ink use at PPTWS
6	Capability for Immediate and simultaneous discovering the involved peoples “signature counterfeit” or other illegal manufacturing at the permit	18	Capability for Immediate and simultaneous controlling the total human resource statistics who are active in the site according to issued permits
7	Capability for Immediate and simultaneous informing total and detail statistics of active permits (cold permits – hot permits – naked flame permits) for top managers	19	Capability for Immediate and simultaneous smart control and monitor a long time and short time process or electrical isolations complementary permits.
8	Capability for Immediate and simultaneous informing: forced complementary sanction for test permits to all other AIPs	20	Capability for Immediate and simultaneous informing: permit temporary stop cases to all other AIPs
9	Capability for Immediate and simultaneous informing active permits at each area which have feedback to other areas (area feedback wised separation) to all other AIPs	21	Capability for Immediate and simultaneous informing all permit-related cases to next shift personal(day shift permit information transfer to night shift personal and vice versa).
10	Capability for Immediate performing risk assessment for each issued permit topics by all area A.I.Ps	22	Capability for Immediate and simultaneous smart control and monitor the validated and revalidated current active permits statistics
11	Capability for Immediate and simultaneous smart control and monitor the closed or canceled permits.	23	Capability for Immediate and simultaneous smart control and monitor the inhibit cases at current active permits
12	Capability for Immediate and simultaneous informing topics of issued and active permits separately (topic-based statistics) to top managers and especially to E.R.T (emergency response team)		

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Following procedures have done to control and eliminate FCCs in PTWS:

1. Training and Meeting
2. More new personnel office permission
3. Keeping one of permits paper at the permit office for more guaranty
4. Area authority writes issued permits number in his notebook
5. All AIPs have verbal coordination (wireless) together
6. All issued permits recorded at permit office book and an excel file
7. Procedure updating

The above results showed that these protective layers are insufficient and ineffective so that the PTWS will lead to failures in four branches of human, environment, equipment, and reputation.

Hence, considering the following items;

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- Refineries vastness, interconnections, and closeness to the residential ports
- Presence of a great number of workforces (native and non-native) in this zone
- The strategic importance of environment issues (water-soil-air) of the zone on the national and international level
- Sustainable development indexes of the zone on national and international effects

It seems necessary to perform some effective corrections in both structural and executive perspectives of currently used paper-based PTWS, to minimize or eliminate accidents and human errors, and leading the system to ALARP.

Investigating and concentering on the performed PTWS reliability analyses and system FCCs, the following seven items were determined as the main core of errors:

1. Capability for Immediate and simultaneous informing the issued permit topics to all other areas AIPs
2. Capability for Immediate and simultaneous informing the issued confined spaces permits to all other areas AIPs
3. Capability for Immediate and simultaneous informing the issued HNF permits to all other areas AIPs
4. Capability for Immediate and simultaneous discovering the involved peoples “signature counterfeit” or other illegal manufacturing at the permit
5. Capability for Immediate performing risk assessment for each issued permit topics by all area AIPs
6. Capability for Immediate Access Record for Missed Permits
7. Capability for Immediate controlling the AIP Competency-based on-field and area wise

Therefore, at the following, a semi-intelligent PTWS with the electronic database is proposed to overcome the deficiencies of the currently used paper-based PTWS, and correct or eliminate the above mentioned FCCs. In the proposed new PTWS, the electronic database is divided into the following main parts.

- Electronically identification of all the involved and responsible persons at permits, to PTWS.
- Electronically definition of all areas of the refinery, to PTWS
- Electronically availability of risks assessments documents of the different activities, in PTWS
- Electronically definition all types of main permits (cold - hot - naked flame) in PTWS
- Electronically definition of complementary permits in PTWS

Corrective actions to create database based on PTWS nine main parts of PBPTWS have been explained in Table 4.

Specialist’s opinion to define the probability values was used to calculate the total average of P.P.E.P and D.P.E.P for pessimist and optimist statuses as shown in Table 1. This mentioned value sample f questions which come from the conditional probability equation were entered Bayesian equation. The total approximate average for 7 prominent FCCs was calculated and has been presented in Table 5:

Continue this research, to calculate the total average of P.P.E.P and D.P.E.P for two status: pessimist and optimist, it is necessary to get a specialist opinion to define the probability values as shown in table 1, by above-mentioned sample f questions which come from the conditional probability equation and such values are put into the Bayesian equation. Applying such values and performing simulation, the total approximate average for 7 prominent FCCs are offered in table 5:

Table 4. Proposed corrective action (protection layers) according to the main FCCs

Proposed corrective action (protection layers) according to the main FCCs	Permit Part No.	FCCs
✓ Make part one electronic ✓ Configuring network share for part one to all AIPs ✓ All AIPs must be identified for D.P.T.W.S EPTWS ✓ All-important items must be inserted ✓ Capability for force cases must be considered ✓ Task supervisor signature must be designed electronically ✓ Daily statistics item must be inserted	1	A,B,C,D,G,I,J,K,L,M,N,O,R,S,T
✓ Make part two electronic ✓ Configuring network share for part two to all AIPs ✓ All AIPs must be identified for D.P.T.W.S ✓ All-important items must be inserted ✓ Capability for force cases must be considered ✓ Area authority signature must be designed electronically ✓ Complementary permits daily statistics item must be inserted and sent to all AIPs	2	B,C,D,E,G,I,J,K,O,Q,,S,U,V,W
✓ Make part three electronic ✓ Configuring network share for part THREE to all AIPs ✓ All AIPs must be identified for D.P.T.W.S ✓ All-important items must be inserted ✓ Capability for force cases must be considered ✓ Area authority and operators signature must be designed electronically ✓ Activity pre-requirements must insert and send to all AIPs	3	A,B,C,D,E,G,J,K,L,M,N,O,Q,R,S,V,W
✓ Make part four electronic ✓ Configuring network share for part four to all AIPs ✓ All AIPs must be identified for D.P.T.W.S ✓ All-important items must be inserted ✓ Capability for force cases must be considered ✓ HSE authority signature must be designed electronically ✓ Activity HSE requirements must be inserted and sent to all AIPs	4	B,C,D,E,G,I,J,K,O,P,S,W
✓ Part 5 registration must be made electronically ✓ AGT personnel must perform the gas test ✓ Gas testing results must be registered electronically ✓ Gas testing unsafe results must urgently be reported to all areas and area authorities	5	D,G,H,I,J,K,O,P
✓ Part 6 registration must be made electronically ✓ CCR field operator must perform primary inhibit and register it electronically ✓ Primary inhibit must immediately report to all areas and area authorities	6	D,G,J,K,N,O,V,W
✓ This part must be signed by a related task supervisor inside the permit office for each shift separately	7	D,E,G,K,R
✓ After AIPs signed the printed permit, they should have a systematic network to inform to all AIPS at all areas ✓ If AIPs do not sign the printed permit, they should have a systematic network to inform validated permits to all AIPS at all areas ✓ If each of AIPs has recognized that permit should be canceled or suspended, permit they should have a systematic network to inform to all AIPS at all areas ✓ They should have a systematic network which can inform next shift	8	D,E,F,G,K,M,N,O,P,Q,S,T,W
✓ After AIPs signed the printed permit, they should have a systematic network to inform to all AIPS at all areas ✓ If AIPs do not sign the printed permit, they should have a systematic network to inform closed or canceled or suspended permits to all AIPS at all areas ✓ If each of AIPs has recognized that permit should be canceled or suspended or closed, permit they should have a systematic network to inform to all AIPS at all areas ✓ They should have a systematic network which can inform next shift	9	D,F,H,I,J,K,P,Q,R,U,V,W

Table 5. Total approximate average of P.P.E.P and D.P.E.P for two statuses: pessimist and optimist for 7 prominent FCCs

TOTAL AVERAGE P.P.E.P		TOTAL AVERAGE D.P.E.P	
OPTIMIST	PESSIMIST	OPTIMIST	PESSIMIST
22.17%	33.22%	21%	23.55%
27.99%		22.27%	

In order to calculate total approximate reliability (success probability level) of P.P.T.W.S and D.P.T.W.S, results of Table 6 entered into following equation:

$$P(R.P.P.T.W.S) = 100 - P(P.P.E.P) = 100\% - 27.99\% = 72.01\%$$

$$P(R.D.P.T.W.S) = 100 - P(D.P.E.P) = 100\% - 22.27\% = 77.73\%$$

The probabilities for 7 prominent FCCs were evaluated for optimist and pessimist statuses. As results showed in Tables 1, 2 it can be concluded that the following logical priority and effectiveness (Table 7) were evident for 7 variables at different statuses.

As shown in diagrams, HSE-MS should consider and provide special controlling and corrective for disconformities probable when if answers for analysis question considered "impossible", then variables 1, 2, 3, 5, and 4 have more negative effects on P.T.W.S: P.P.T.W.A and D.P.T.W.S in both optimist and pessimist statuses.

Comparisons results showed that the calculated D.P.T.W.S error probabilities are significantly less than for P.P.T.W.S at optimist and pessimist. In the other words, the reliability of D.P.T.W.S was better (more) than P.P.T.W.S and it means that accident probability at D.P.T.W.S was lower, optimized, and more reliable system.

According to the results in Table 2, the total error probability average for P.P.T.W.S and D.P.T.W.S was calculated 29.25% and 22.05%, respectively. It is clear that the D.P.T.W.S using and executing for a high-risk plant such as gas refinery plants may decrease accident in an effective way.

According to the results in Table 3, the total reliability average for P.P.T.W.S and D.P.T.W.S was determined 70.75% and 77.95%, respectively. It can be concluded that the D.P.T.W.S using and executing for a high-risk plant such as gas refinery plants may decrease accident significantly.

According to the results in Table 4, logical priority and effectiveness for FCCs, which have an important role on P.T.W.S the reliability were determined respectively: B-A-C-E-F-G-D. It means that B and A impact significantly the reliability of the system and to improve mentioned factors we can optimize P.P.T.W.S to D.P.T.W.S and accordingly remove or significantly decrease accidents.

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Table 6. Total approximate average of P (R.P.P.T.W.S) and P (R.D.P.T.W.S) for two statuses: pessimist and optimist for 7 prominent FCCs.

TOTAL AVERAGE P (R.P.P.T.W.S)		**TOTAL AVERAGE P(R.D.P.T.W.S)**	
OPTIMIST	PESSIMIST	OPTIMIST	PESSIMIST
77.23%	66.78%	79%	76.45%
72.01%		77.73%	

Table 7. Logical priority and effectiveness for FCCs, which have an important role in P.T.W.S reliability

FCCs	**Reliability effectiveness priority for P.P.T.W.S**		**Reliability effectiveness priority for D.P.T.W.S**	
	STATUS		**STATUS**	
	OPTIMIST	**PESSIMIST**	**OPTIMIST**	**PESSIMIST**
R(B)	74%	63%	83%	70%
R(A)	78%	67%	86%	74%
R(C)	74%	62%	83%	70%
R(E)	72%	60%	82%	70%
R(F)	84%	73%	90%	78%
R(G)	82%	73%	89%	77%
R(D)	70%	60%	80%	69%
R (TOTAL AVERAGE)	**77.23%**	**66.78%**	**79%**	**76.45%**

DISCUSSION

As mentioned earlier, Pars Special Economic Energy Zone (PSEEZ) was established in 1998 to extract oil and gas from South Pars/North Dome Gas-Condensate field [19]. This zone is located in Persian Gulf coast approximately 100 km away from the South Pars Gas Field. PSEEZ Development projects in PSEEZ covers 10000 hectares of land with 6000 hectares of industrial installations and infrastructures, expected to have almost 60000 experts and workers inside the PSEEZ during the development period [20]. In gas refinery plants, processes include very toxic, flammable, and detonative gases, as well as many other hazardous chemicals, added or produced during gas refining and purification process.

Having considered these characteristics, gas refinery plants in PSEEZ were categorized as a high risk and hazardous workplace. Accordingly, it is necessary to plan and execute active HSE-MS and it's

subsystems to decease and finally eliminate accidents as low as reasonably practicable level (ALARP). PTWS is one of the HSE-MS sub-systems that play important and effective roles in achieving HSE-MS goals. As mentioned, the currently used PTWS in South Pars zone (PSEEZ) refinery plants is based on paper-based permit developed by Total Company [21].

This study-based system was consisted nine parts. In this system, different experts were engaged in accomplishing a PTW task, including task supervisor (who plans and leads implementer team), area authority (the one who is the head of a specific area in the refinery), area operator (the one who performs orders of the area authority), HSE authority (head of HSE at a specific area of the refinery), authorized gas tester (AGT, a member of HSE expert who is responsible for gas testing), and central control room (CCR) operator (who is responsible for INHIBIT (temporarily changing or suspending automatic safety and firefighting control systems to a manually controlled one and vice versa).

To describe this paper-based procedure briefly, it can be noted that the current paper-based PTWS comprised of three stages, as shown in **Error! Reference source not found.**2. In part 1, one day before activity start, the task supervisor applies for required permits and determining job title, job kind (cold-hot-naked flame), time limit, location, subcontractor, primary requirements, primary attachments, workers statistics, and equipment tag number. In the second part, if complimentary permits needed the area authority would determine required complementary permits. These complimentary permits included excavation, electrical isolation, process isolation, post welding heat treatment (PWHT) sanction for the test, road closed, utility isolation, and radiography test. Then the task supervisor will insert the complementary permits in the main permit. In the third part, the area authority identifies process and equipment safety requirements, and the area operator should perform his requests. HSE requirements identified by P.T.W HSE authority in the 4th part, and then the task supervisor must perform his orders. If PTW HSE authority identified the priority of the gas test at part 4, then the AGT must performed the gas test.

In a parallel procedure, if area authority identifies INHIBITS in part three, the CCR field operator must perform it. The final part of the activity requirements preparation stage is the written commitment of the task supervisor regarding all considerations and safety requirements. The task permitted to start after the task supervisor, HSE supervisor, operator authority, and area authority signed the permit in 8th part. It is worth noting that permit revalidation proceeds daily. In the third stage (permit compilation) the permit confronts with three situations including: *a*. permit closed: permit date and time finished, *b*. permit suspended: at special statuses permit had temporarily suspended by HSE or Area authority, *c*. permit canceled: at special dangerous conditions or high risk, responses all permits would canceled by HSE. Finally, task supervisor should give back main and complementary permits to the central permit office.

To execute Bayesian probability, 7 prominent FCCs at P.T.W.S, were selected and considered as a sample. According to Table 2 and the equation, the following FCCs offered as interpretative questions. These FCCs were the most important and critical functions of P.T.W.S at commissioning and start-up phases of gas refinery plant (Figure 2).

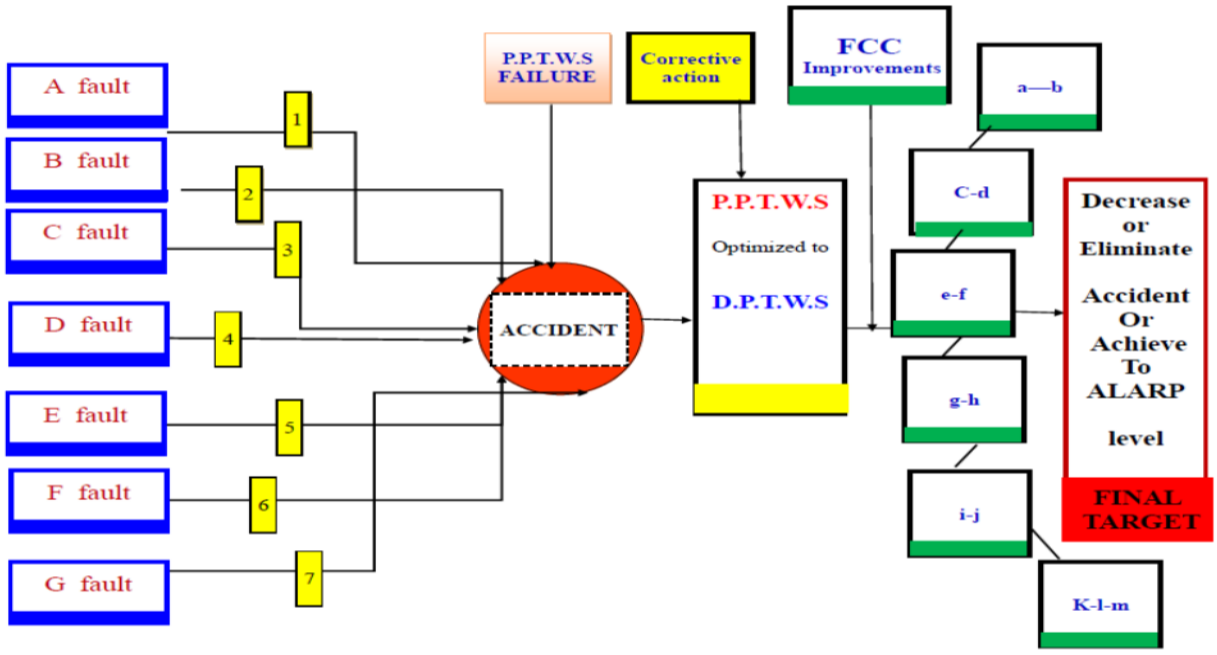

Fig. 2. Selecting, analysis, and calculating the reliability for 7 prominent FCCs at P.P.T.W.S and D.P.T.W.S by Bayesian probability method.

Table 2. Reliability analysis using Bayesian probability method for different status of FCCs

IF	AND	SO	P.P.E.P		D.P.E.P	
			OPTIMIST	PESSIMIST	OPTIMIST	PESSIMIST
A is possible	B,C,D,E,F,G are impossible		22%	33%	14%	26%
B is possible	A,C,D,E,F,G are impossible		26%	37%	17%	30%
C is possible	A,B,D,E,F,G are impossible		26%	38%	17%	30%
D is possible	A,B,C,E,F,G are impossible		30%	40%	20%	31%
E is possible	A,B,C,D,F,G are impossible		28%	40%	18%	30%
F,G are possible	A,B,C,D,E are impossible		16%	27%	10%	22%
A,E are possible	B,C,D,F,G are impossible		18%	27%	11%	23%
C,D are possible	A,B,E,F,G, are impossible		20%	29%	13%	26%
A,G are possible	B,C,D,E,F are impossible		19%	28%	12%	24%

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If P (A) is possible and P(B, C, D, E, F, G) are impossible, SO, how much is P.P.E.P and D.P.E.P for optimist and pessimist statuses?

If P (B) is possible and P(A, C, D, E, F, G) are impossible, SO, how much is P.P.E.P and D.P.E.P for optimist and pessimist statuses?

If P (A, D, F) are possible and P(B, C, E, G) are impossible, SO, how much is P.P.E.P and D.P.E.P for optimist and pessimist statuses?

If P (F, E, G) are possible and P(A, B, C, D) are impossible, SO, how much is P.P.E.P and D.P.E.P for optimist and pessimist statuses?

And then, the results of probability for each statuses in Table 1, will be a substitute in the following Bayesian general probability equation [17]:

$$P(A) = P(A|B1)P(B1) + \cdots + P(A|Bn)P(Bn) \quad (1)$$

Some examples of Bayesian probability calculation for Table 1:

P.P.E.P = [Probability (Ai/Bi,Ci,Di,Ei,Fi,Gi)× P(Bi)× P(Ci)× P(Di)× P(Ei×) P(Fi) ×P(Gi)]+ [P(Ai/Bp,Ci,Di,Ei,Fi,Gi)× P(Bp)× P(Ci)× P(Di)× P(Ei)]+…

D.P.E.P =[Probability (Ai/Bi,Ci,Di,Ei,Fi,Gi)× P(Bi)× P(Ci)× P(Di)× P(Ei) × P(Fi) × P(Gi)]+ [P(Ai/Bp,Ci,Di,Ei,Fi,Gi)× P(Bp)× P(Ci)× P(Di)× P(Ei)]+…

Note:

P= probability

Ai= A is in impossible status

Ap= A is in possible status

This study will have some limitations in a typical dissertation that may be related to the following points; especially, implementation of the data collection method through different areas in the research zone, reliability analysis by Bayesian probability and sample size depends on the nature of the research problem. So, in the small size of samples, statistical tests would not be able to identify significant relationships within the data set. And also, as mentioned previously FCCs of PTWS related to the experience of trustees and experts so that is disconformities potentials.

CONCLUSION

As discussed in Pars Special Economic Energy Zone gas refineries (PSEEZ), these inherent PTWS errors and faults may cause system operation accidents and finally system failures and catastrophic disasters.

Therefore to analysis fault creator case in permit to works system, which currently logical management applying changes at the current PTWS, it is possible to decease and finally eliminate accidents as low as reasonably practicable (ALARP) level at gas refinery plants. So that, all 7 prominent mentioned fault creator cases (FCCs) of PTWS will be removed or corrected and for this reason the probability of faults will be reduced significantly. Therefore these results may reduce human errors and also accidents rates significantly in four categories including human, environment, material (equipment), and reputation.

Moreover, MOC logical and precise implication may alter P.P.T.W.S to D.P.T.W.S in PTWS as one of the most important and key subsystems of HSE-MS, by executing a logical and precise MOC, changing P.P.T.W.S to D.P.T.W.S. So it may significantly eliminate and/or decrease the accidents and ALARP will be achievable. It should be noted that PTWS is only one of the HSE- MS subsystems and clearly will be more effective along with optimizing other subsystems.

The important results and points of this study were described as bellow after performing the Bayesian probability analysis into 7 important and critical variables, which can be fault creator at mentioned conditions, for both PTWS and DPTWS in pessimist and optimist statuses.

The total error probability average for P.P.T.W.S and D.P.T.W.S were 27.99% and 22.27% respectively. It can be concluded that the D.P.T.W.S using and executing for a high-risk plant such as gas refinery plants may decrease accident significantly.

The total reliability average for P.P.T.W.S and D.P.T.W.S were 72.01% and 77.73% respectively. It is clear that the D.P.T.W.S using and executing for a high-risk plant such as gas refinery plants is more effective and definitely by precise execution, may decrease accidents significantly.

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It should be notified that P.T.W.S is only one of the HSE- MS subsystems and clearly will be more effective along with optimizing other subsystems.

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CONFLICTS OF INTEREST

The authors have no conflict of interests to declare.

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