Research Journal of Applied Sciences, Engineering and Technology 6(6): 978-982, 2013
DOI:10.19026/rjaset.6.4001
ISSN: 2040-7459; e-ISSN: 2040-7467

Submitted: October 17, 2012 Accepted: December 19, 2012 Published: June 30, 2013

Research Article

Hazards Forecasting and Weights Determination during Operation and Maintenance of Petrol Fuel Station

[1]M.M. Ahmed, [1]S.R.M. Kutty, [1]Mohd Faris Khamidi, [1]I. Othman [2]P.D.D. Dominic and [2]Olisa Emmanuel
[1]Department of Civil Engineering,
[2]Department of Computer and Information Science, Universiti Teknologi PETRONAS (UTP), Malaysia 31750 Tronoh, Perak, Malaysia

Abstract: Petrol Fuel Stations (PFS) is the most commonly available hazardous facility within urban and rural areas. Hazardous materials such as petrol, diesel, Compressed Natural Gas (CNG) and kerosene oil normally sell and stores at PFS. PFS can be considered as small refinery within the city. A 3.5 year study conducted and 3216 non-compliances were recorded from PFS located in various cities of Pakistan. The operating company was ISO 14001 and OHSAS 18001 certified. The recorded non-compliances during study period were categorized into 8 potential factors. These were Housekeeping (HK), Transportation Hazard (TH), Slips, Trips and Falls (STF), Carelessness (C), Fire Risks (FR), Electrical Fault (EF), Miscellaneous Cases (MC) and Medical Treatment Cases (MTC). Analytical Hierarchy Process (AHP) was used and categorized 8 factors were prioritized. The same data was further classified based upon to cause fatality, accident, incident and near miss cases. A total numbers of 14, 426, 975 and 1804, fatality, accident, incident and near miss cases were recorded. With application of Exponential Smoothing method the fatalities, accident, incident and near miss cases for the years 2011, 2012 and 2013 were forecasted. The results of AHP and forecasted hazards will be presented and discussed in this study. It is hope that the both approaches will assist health and safety professionals for future hazards predictions and hazards weights determinations. Health and safety practitioners can take remedial and preventative measures by using past data with utilization of proposed techniques.

Keywords: Contributing factors, forecasting, hazards, safety conditions, unsafe acts and unsafe conditions

INTRODUCTION

A petrol filling station is a hazardous facility and it need special care in the design, construction, installations and maintenance of its components so that they remains safe throughout the life span of the station and not to cause explosion or other untoward incidents (Ahmed *et al*., 2011a). Petrol filling stations are particularly hazardous workplaces. They store and sell a highly flammable liquid. Fire hazards, static electricity, air pollution evoked by aromatic organic compounds are found to be the major causes of accident/incident occurrences at petrol fuel stations. Process and behavioural aspects identified as the potential accident causes during operation and maintenance of petrol fuel stations (Ahmad *et al*., 2010).

Petrol fuel stations are normally available in rural and urban areas. Their presence for smooth economic operation is essentially viable. The level of risk posed by these hazards is different at different fuel stations. The numbers of petrol fuel stations are increasing continuously due to increase in economic development and growth.

LITERATURE REVIEW

Petrol fuel stations operation is unique as compared to many other businesses. For smooth operation of petrol fuel station it needs good safety attitude by visitors coming to take fuel, fuel operating company and the contractors. A minor negligence can cause fire and explosion that can generate heavy losses. The number of vehicles to determine the required number of petrol fuel stations was also highlighted by Melaina (2003) and Nicholas and Johnson (2005). The studies conducted didn't highlight the hazardous impacts of PFS's on the nearby residential areas, environment, soil and water bodies. A petrol fuel station has potential hazards to the people, asset, environment and reputation of an operating company (Ahmed *et al*., 2011b). Hazards posed by activities were different from one operating sector to another. The hazards that can pose a significant risk to the construction industry are not the same as for the petroleum industry. The non-

Corresponding Author: Mirza Munir Ahmed, Department of Civil Engineering, Universiti Teknologi PETRONAS (UTP), Malaysia 31750 Tronoh, Perak, Malaysia

compliances recorded during operation and maintenance of PFS produced variety of hazards that may cause fatalities, accidents, incidents and near miss cases. Therefore, to prevent unwanted scenarios, each sector's hazards require a different strategy. A petrol fuel station is a unique facility that stores and sells a flammable and hazardous material in close vicinity within rural and urban areas. A fuel station poses potential hazards to the people, assets, environment and reputation of an operating company. Hazards related to fuel station operations can be mainly divided into two categories, i.e., onsite hazards and off site hazards. There are other potential hazards in fuel station operations which makes them unsafe. Activities such as carelessness, maintenance, housekeeping, slips, trips and falls, transportation hazard, major and minor injuries, robberies and snakebites have a potential to create unsafe conditions.

FORECASTING OF UPCOMING HAZARDS

The exponential smoothing method was used to forecast the future occurrences of fatality, accident, incident and near miss cases. The data for the years 2007, 2008, 2009 and 2010 were used to forecast the number of fatality, accident, incident and near miss cases for the years 2011, 2012 and 2013.

The equation for an exponential smoothing forecast was:

$$Ft = (1-\propto)Ft + \propto A(t-1) \quad \text{(Davis and Heineke, 2005)} \qquad (1)$$

where,

Ft = Exponentially smoothed forecast for period t

F t-1 = Exponentially smoothed forecast made for the prior period

At-1 = Actual demand in the prior period

α = Exponential smoothing constant

The equation states that the new forecast is equal to the old forecast plus a portion of the error (the difference between what actually occurred and the previous forecast).

ANALYTICAL HIERARCHY PROCESS (AHP)

The AHP approach was used to prioritize the hazard contributing factors (HCFs) to support the HSE professionals in their decision making. It aims to rank the HCFs. In the AHP, the HCFs were presented in a hierarchical structure and the decision maker was guided throughout a subsequent series of pair wise comparisons to express the relative strength of the elements in the hierarchy. In general, the hierarchy structure encompasses three levels; the top level represents the HCFs and the lowest level has the duration in which the non compliances occurred. The intermediate level contains the evaluated criteria under which each HCF was evaluated. Figure 1 depicts the structure of the problem hierarchy.

There were many ways to obtain a preference: the measurement scale proposed by Saaty (1987) was used in many studies. Table 1 illustrates a glimpse of the decision maker's judgment and preference of the criteria with pair wise comparisons . This measurement scale enables the HSE professionals to determine the significance level among the criteria.

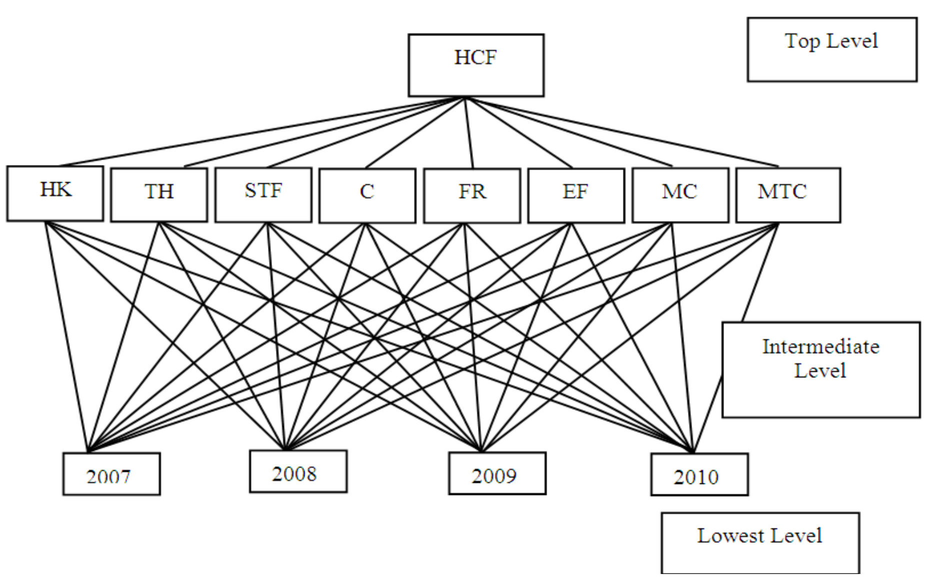

Fig. 1: AHP problem hierarchy

Table 1: AHP measure scale (Saaty, 1987)

Value	Preference
1	Equal Importance
3	Moderate Importance
5	Strong Moderate Importance
7	Very strong Moderate Importance
9	Extreme Moderate Importance
2,4,6,8	For comparison between the above values

This measure scale includes 1-9 scale points; each point represents a different degree of preference.

By using the measure scale and comparing each HCF to another, the original matrix of the criteria was composed. The data used in the original matrix of the criteria produced an accurate estimate of the criteria weights. The weights provide a measure of the relative strength and importance of each criterion. The whole process can be broken down into the following steps:

- Compute the total values in each column
- Divide each single value by its column total
- Calculate the averages of each row

The final scores obtained for each HCF across each criterion was determined by multiplying the weight of each criterion with the weight of each HCF. The HCF that got the highest score was suggested as the most significant HCF.

RESULTS FOR FORECASTING OF HAZARDS FOR THE YEARS 2011, 2012 AND 2013

Forecasting is an important aspect to predict the non compliances that may occur in the future. Normally, past years' data was used to predict the future hazard occurrences. In a similar way to predict the upcoming non compliances during the operation and maintenance of the petrol fuel stations, the 3.5 year study data was used. The occurrences of fatality, accident and incident and near miss cases were predicted.

Table 2 illustrates the number of fatality, accident, incident and near miss cases that was reported during the data collection period. An Exponential Smoothing method was used and the number of fatality, accident, incident and near miss cases for the years 2011, 2012 and 2013 was forecasted. The values were forecasted by using equation 1. The exponential smoothing constant (α) values were used as 0.6 and 0.4 with the forecasted and actual values, respectively. The forecasted values for each year from 2007 to 2013 were calculated and compared. The forecasted value for the year 2007 was calculated by taking the average of the number of fatality cases reported in the years 2007, 2008 and 2009. Therefore, the forecasted numbers of the fatality cases for the year 2007 were:

$$F\ (2007) = (1+5+1)/3 = 2.33$$

Table 2: Summary of actual fatality, accident, incident and near miss cases occurrences during 3.5 year study period

No	Period	Fatality	Accident	Incident	Near Miss
1	2007	1	47	239	387
2	2008	5	90	352	756
3	2009	1	101	238	562
4	2010	7	188	146	99
	Total	14	426	975	1804

Table 3: Summary of forecasted values for fatality, accident, incident and near miss cases for the year 2011, 2012 and 2013

No	Period	Fatality	Accident	Incident	Near Miss
1	2011	5	150	195	296
2	2012	4	127	224	414
3	2013	4	136	212	367

The calculation for forecasted values for fatality cases was determined as:

$$F_{(2008)} = 0.4\ F_{(2007)} + 0.6\ A_{(2007)}$$
$$F_{(2008)} = 0.4\ (1) + 0.6\ (2.33)$$
$$F_{(2008)} = 1.798$$

The forecasted values for each parameter. i.e., fatality, accident, incident and near miss in every year was determined in a similar way as described above and are presented in Tabular form in Table 3.

Table 3 depicts the predicting values for fatality, accident, incident and near miss cases for the years 2011, 2012 and 2013. It can be observed in Table 3, that similar to past years the frequency for occurrences of near miss cases were still higher as compared to accident and incident cases. The chances for occurrences of fatalities still exist. Therefore, HSE professionals with the management committee should take preventive measures and closely monitor the HSE management system at all PFS's. Accident and incident case prediction was also noticed to be higher. Therefore, close monitoring was also required to reduce occurrences of accident and incident cases.

RESULTS OF AN AHP

An AHP (analytical hierarchy process) was designed to solve decision making problems. It is a tool that combines qualitative and quantitative analysis and successfully implementation in many fields of health and safety (Jin-yu *et al*., 2008). The AHP application was described by Saaty (1987) in detail. It was also highlighted by Perçin (2006) that AHP developed by Saaty has become a popular approach and has been used in a broad variety of situations by various researchers. Furthermore, apart from the occupational health and safety discipline, the successful application of the AHP have been reported in marketing, economics, finance, public policy, education, medicine

Table 4: Cumulative data related to HSE non-compliances during 3.5 years study period

No	Variable	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1	HK	11	2	4	14	8	9	17	35	16	10	17	13	156
2	TH	68	43	57	54	47	39	84	85	74	70	50	68	739
3	STF	53	66	91	19	28	33	46	74	66	29	45	53	603
4	C	36	25	30	38	15	25	34	52	58	40	62	34	449
5	FR	8	8	5	18	3	3	4	8	4	9	4	5	79
6	EF	26	8	25	11	8	18	23	17	24	21	22	15	218
7	MC	45	63	51	48	32	40	83	72	87	56	83	56	716
8	MTC	18	10	33	13	9	10	29	27	19	28	30	30	256
	Total	265	225	296	215	150	177	320	370	348	263	313	274	3216

Table 5: Original criteria matrix

	HK	TH	STF	C	FR	EF	MC	MTC
HK	1.00	3.00	9.00	7.00	9.00	3.00	5.00	3.00
TH	0.33	1.00	3.00	5.00	5.00	3.00	5.00	7.00
STF	0.11	0.33	1.00	7.00	3.00	3.00	5.00	7.00
C	0.14	0.20	0.14	1.00	5.00	3.00	5.00	7.00
FR	0.11	0.20	0.33	0.20	1.00	7.00	5.00	5.00
EF	0.33	0.33	0.33	0.33	0.14	1.00	3.00	7.00
MC	0.20	0.20	0.20	0.20	0.20	0.33	1.00	5.00
MTC	0.33	0.14	0.14	0.14	0.20	0.14	0.20	1.00
Total	2.57	5.41	14.15	20.88	23.54	20.48	29.20	42.00

Table 6: Normalized criteria matrix

	HK	TH	STF	C	FR	EF	MC	MTC	Weights
HK	0.39	0.55	0.64	0.34	0.38	0.15	0.17	0.07	0.34
TH	0.13	0.18	0.21	0.24	0.21	0.15	0.17	0.17	0.18
STF	0.04	0.06	0.07	0.34	0.13	0.15	0.17	0.17	0.14
C	0.06	0.04	0.01	0.05	0.21	0.15	0.17	0.17	0.11
FR	0.04	0.04	0.02	0.01	0.04	0.34	0.17	0.12	0.10
EF	0.13	0.06	0.02	0.02	0.01	0.05	0.10	0.17	0.07
MC	0.08	0.04	0.01	0.01	0.01	0.02	0.03	0.12	0.04
MTC	0.13	0.03	0.01	0.01	0.01	0.01	0.01	0.02	0.03
Total	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

and sports. Moreover, AHP applications have been proven to be well tested and supportive in many other decision situations concerning evaluation and selection processes (Kiker *et al*., 2005). The AHP approach was helpful to address selection, evaluation, resource allocation, benchmarking, quality management, health care and strategic planning as well. The AHP provides an environment that creates simplicity and easiness in decision making process.

Table 4 illustrates the cumulative data related to the non-compliances during the 3.5 years study period. The non-compliances during the study period were categorized into eight variables. The first column contained the eight variables. These eight variables were Housekeeping (HK), Transportation Hazard (TH), Slips, trips and falls (STF), Carelessness (C), Fire Risks (FR), Electrical Fault (EF), Miscellaneous Cases (MC) and Medical Treatment Cases (MTC). The rest of the columns represents the duration in months from January to December. Table 4 consisted of a 6 month duration of data for the year 2007 from July to December and a three year duration covering the years 2008, 2009 and 2010.

By using the measurement scales in Table 1 and comparing each HCF to another, the original criteria matrix was composed. Table 5 gives a glimpse of the decision maker's judgment and preference of the criteria with pairwise comparisons.

Generally, for any pairwise comparison matrix, 1s have been placed down the diagonal from the upper left hand corner to the lower right hand corner then a comparison of the respective criteria is made. Considering Table 4, HK has a moderate importance with TH, therefore 3 has been placed in the intersection cell. STF has an extreme importance with HK, therefore 9 has been placed in the intersection of HK in the first row. By applying the same method all the rest of the cells were filled. Since comparing row 1, the other can similarly be compared.On the flip side of the diagonal, when TH was compared with HK it was 1/3 and so on.

Once these comparisons had been made, the data were used to determine the weights of the criteria; the process, as was summarized before, was in three steps: calculating the total of each column, dividing each value obtained by its column total and calculating the averages of the rows. Table 6 depicts the final results and it illustrates the weights for each HCF.

The last column in Table 6 includes the weights of all the eight involved HCFs in this process. It shows that the final weights of Housekeeping (HK), Transportation Hazard (TH), Slips, Trips and Falls (STF), Carelessness (C), Fire Risks (FR), Electrical Faults (EF), Miscellaneous Cases (MC) and Medical Treatment Cases (MTC) were 0.34, 0.18, 0.14, 0.11, 0.10, 0.07, 0.04 and 0.03.

DISCUSSION

A study was consisted of forecasting of fatalities, accident, incident and near miss cases that may occur in coming years. 3.5 year of data used and 3216 non-compliances were categorized into occurrences of fatalities, accident, incident and near miss cases. By using exponential smoothing approach the predicted numbers of cases for the year 2011, 2012 and 2013 were determined and presented in Table 3.

The same data was categorized into 8 factors by using Analytical Hierarchy Process (AHP), weights for each factor was calculated. The results of weights determination were presented in Table 6. It can be observed that highest weights. i.e., 0.34 was calculated for HK. Weights calculated for TH, STF and C, were 0.18, 0.14 and 0.11, respectively. FR, EF, MC and MTC, got weights, 0.10, 0.07, 0.04 and 0.03, respectively. Although the determined weights for FR, EF, MC and MTC were low but factors cannot be considered of lower value. The cases pertaining to these activities occurrences were less in numbers but incurred with higher severity level.

CONCLUSION

By considering the results of study that was based upon 3.5 year of study period data it can be concluded that safety conditions at PFS were not safe. They need more safety measures to avoid occurrences of any unwanted scenario during operation and maintenance.

ACKNOWLEDGMENT

The author would like to acknowledge the Universiti Teknologi PETRONAS (UTP) for providing study opportunity and use of precious resources. The author is highly grateful to the petrol fuel stations supervisors who helped him to collect data and their input during the study.

REFERENCES

Ahmad, M.M., S.R.M. Kutty, M.S. Azmi and M.F. Khamidi, 2010. Application of at-risk behaviour analysis and improvement system (arbais) model in construction industry. Malays. Constr. Res. J., 7(2): 27-38.

Ahmed, M.M., S.R.M. Kutty, A.M. Shariff and M.F. Khamidi, 2011a. New and improved safety and risk assessment model for petrol fuel station. Proceeding of National Postgraduate Conference (NPC 2011). Kuala Lumpur, pp: 1-10.

Ahmed, M.M., S.R.M. Kutty, A.M. Shariff and M.F. Khamidi, 2011b. Petrol fuel station safety and risk assessment framework. Proceeding of National Postgraduate Conference (NPC, 2011). Kuala Lumpur, pp: 1-8.

Davis, M.M. and J.N. Heineke, 2005. Operations Management: Integrating Manufacturing and Services. McGraw-Hill, Irwin.

Jin-yu, G., E.Z. Zhong-bin, S. Qing-yun, 2008. Study and applications of analytic hierarchy process. China Safety Sci. J., DOI: CNKI:SUN:ZAQK.0.2008-05-026.

Kiker, G.A., T.S. Bridges, A. Varghese, P.T. Seager and I. Linkov, 2005. Application of multicriteria decision analysis in environmental decision making. Integr. Environ. Assess. Manag., 1(2): 95-108.

Melaina, M.W., 2003. Initiating hydrogen infrastructures: Preliminary analysis of a sufficient number of initial hydrogen stations in the US. Int. J. Hydrogen Energ., 28(7): 743-755.

Nicholas, M. and N. Johnson, 2005. Rural needs for hydrogen station coverage. Proceeding of the National Hydrogen Association (NHA) Annual Hydrogen Conference. Washington, D.C.

Perçin, S., 2006. An application of the integrated AHP-PGP model in supplier selection. Measur. Bus. Excell., 10(4): 34-49.

Saaty, R.W., 1987. The analytic hierarchy process-what it is and how it is used. Math. Modell., 9(3-5): 161-176.