

Risk Assessment and Crisis Management in Gas Stations

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ABSTRACT: Filling stations inside the urban environment are known as one of the existing and potential dangers in cities which according to their centralized fire load can be of high safety importance. Tehran holds 101 active filling stations faced to extreme accidents and high explosion potentials. In this study, 59 out of 101 gas stations were investigated under the fire risk assessment implementation. By the application of the existing standards, a checklist consisting of the entire hazards related to filling stations fire safety was organized, then customers' behavior of smoking and usage of mobile phones were assessed and accounted for determination of probability of fire. Finally, using Williams-Fine and FMEA methods along with an assessment providing model for under study filling stations, the fire risk measurements and estimations were performed. By means of a questionnaire and the related experts' viewpoints, the impact of each parameter in the probability and severity of fire in the filling stations were determined and applied to risk calculations. Also experts' viewpoints, information and data were used for determination of risk tolerance. The results showed that about 68 % of filling stations in Tehran suffer from poor conditions and improper constructions to face risks and crisis. This shows inadequate implementation of risk and crisis management and also inadequacy of manpower training in fire extinguishing techniques. Besides, just three of these gasoline stations were equipped with automatic fire extinguishing system. Regarding preparation for encountering critical conditions, most of the personnel were trained to extinguish fire at gas stations, but only 5 % of them were informed on crisis management. Thus, they attempted to execute a maneuver to be well-prepared when there is urgency. Therefore, prompt and urgent improvements, as well as training are needed through application of crisis management in all directions.

Key words: Risk assessment, Fire, Filling station, Urban environment, Crisis management

INTRODUCTION

Today, urbanization problems in mega cities have become a threat for human community. The records of accidents concerned with gas stations in Korea showed that 41 accidents have occurred from 1992 to 2003 that 25 cases (61%) were fire and explosions (it is noteworthy that they are related to LPG pumps). In one of these accidents, the amount of damage was 13 million dollars (park *et al.*, 2006). According to the informal statistics obtained from 2002 to 2006 in Tehran, 22817 fires have been reported (6787 cases in 2004 ; 7846 in

2005 ; 8184 in 2006 ; respectively), from which 480 cases were related to hazardous places, such as gas stations (131 in 2004 ; 161 in 2005 ; 184 in 2006). To control and manage the risks associated with such places, it is necessary to design an appropriate risk assessment system, so that the levels of risk would be assessed and a desired systematic controlling program would be organized. In a report released from crown HSE in 2002, some stages have been mentioned for primary study of the level of risk from hazardous material (Coshh, 2002). The primary stage is the

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study of neighboring places (Bateman, 2006). In a report released by British Ministry of defense in 1996 conditions of the tanks in which hazardous materials are stored were mentioned and their establishment are discussed (HSMO, 1996). Fire risk assessment is a management tool which helps the managers in their decision-making process. In the model presented by Sui in 2007, factors, including fire spread, use of fire extinguishing and fire alert, fire load and temperature increase in the fire, considered to be affective in fire risk assessment (Sui *et al.*, 2007). In a paper presented by Smolin and Kirillov (2007), the importance of risk assessment is mentioned in places where a large amount of fuel is stored. In this paper, important factors such as the state of fuel, transmission lines, fire extinguishing system (particularly, foam system), electricity system, construction analysis and sampling methods, analysis of leaking fuels and safety values in pipes and tanks were taken into consideration (Smolin and Kirillov, 2007). In the decision-making model provided for fire risk assessment based on the local inhabitant live the involved factors include automatic fire extinguishing systems manual detector, sonar system specialist, fire fighters and smoke alarming system. In this study depending on how much these methods are used, some scenarios have been prepared in which the time required for evacuation and the time needed for fire fighting were determined and have been assessed (Chu *et al.*, 2007). Holborn (2002) studied the use of statistics of accidents and fire occurred in previous years, as a proper method to specify the probability of fire accidents assessed in different locations with different land uses factors. Individual's cautiousness level, usage, construction materials used in flooring, personal characteristics such as language, age, etc. can create errors in estimating the results which needs to be taken into consideration. This indicates that in order to assess the risk of fire correctly, all the effective factors on the intensity and the probability of fire accident should be considered. To assess the risk of fire in inflammable material's tanks, methods such as HAZOP and Even Tree can be used (Holborn, *et al.*, 2002). In 2004, Barmatic and Libisova recommended HAZOP and IAEA-TECDOC-727 using Event Tree Technique for assessing the risk of fire in gasoline storage

tanks (Bernatik and Libisova, 2004). Even Tree method is used to assess the levels of risk in a L.N.G. station. In this method, factors such as human errors, the state of tanks, water pipes, vandalism, repair deficiencies, land uses for the areas around the gas station and fire extinguishing system were considered (Melcher and Feutrill, 2001).

MATERIALS & METHODS

To assess the risk of fire in gas station, first by asking information from Tehran Distribution and Refining Company, the number of stations throughout Tehran were identified, then from 22 districts of Tehran municipality, 14 districts were sampled as clusters. Therefore, all of the filling stations in these districts were assessed. The entire stations under the assessment were 59 (59% of all action stations in Tehran). To identify the existing risk and to conform that to associated standards a check list was used. William-Fine and FMEA methods were used in which the ranking Table 1 to 3. Based on effective parameters in fire risk assessment, risk assessment process in gas station is illustrated in Fig.1. (MacIntyre *et al.*, 2007) (Bateman, 2006). According to the presented model (Fig. 1). probability, intensity and fire detection are assessed by their parameters. Thus, that parameters, including the state of earth system and fuel tanks, identifying system for probable leakages, the pumps and fuel reception systems would be evaluated based on concerned standards and finally the behavior of the customers in smoking and using mobile phone was assessed. For this purpose, according to the value determined for each parameter (if not inconsistent with the standard) its amount will be subtracted from 10 and finally probability rank will be calculated. For fire intensity, factors such as distance from the nearest fire station, automatic fire extinguishing systems, existence extinguishing valve close to the gas stations, suitability of manual fire fighting systems and the location of the stations are considered, and in case of any conformity with the standards, the value of that parameters will be subtracted from 100. The resulting figures show the risk intensity rank. In the case of fire detection, parameters such as alarm systems, suitability of alarming systems, monitoring systems for testing concentration of inflammable materials linking of

the filling station to the fire brigades via intranet were taken into consideration. While, in case of unconformity of any items with the related standard, its value will be subtracted from 10 and the obtained value will be the detection value. It is necessary to mention that all the parameters net value are based on the received comments of related experts and the data collected from the questioners. The amount of final risk was calculated by multiplying three parameters of intensity, probability and detection by each other. Table 4 was used to interpret the obtained data. Risks ranking were determined by experts' viewpoints and the available data and in formations available in the fire extinguishing centers. To compare the data, means and standard deviations data, and also to compare the obtained results in

private and governmental petrol station, T.test - pair were used.

RESULTS & DISCUSSION

The obtained information from Tehran's distribution and refining Company concluded that there are 112 gas stations throughout Tehran, which 11 of them is inactive and 101 of them are active. Of all the specified station, 81 are private and 31 are governmental. In this study, 51 assessed stations are located in Tehran municipality shown in Fig. 2. Of all assessed station, 9 had both diesel and gasoline, and 50 had only gasoline. In this study, there were no stations supplying only diesel. The number of stations with less than 10 installed pumps was 33; among 10 to 15 pumps were 14 and more than 15 pumps were 12, as illustrated in Fig .3.

Table1. Detection factors and its indices

No	Description of detection	Rank
1	There is no detection and alarming system	10
2	There is only a manual alarming system	8
3	There is only an automatic fire detection and alarming system	6
4	There is only a detection system for concentration of inflammable materials with automatic alarming	4
5	There are a monitoring system for concentration of control inflammable materials and automatic alarm system	1
6	There are a detection and monitoring system for concentration of inflammable materials and intranet system linked to central fire station	.5

Table 2. Decision-making factors and the probability rank of fire

No	Description of detection	Rank
1	Unsuitable Earth system not regularly tested, inappropriate state of fuel storage tanks and pumps, lack of alarming signs, inappropriate entrance and exit ways, in appropriate reception system.	10
2	Unsuitable Earth system not regularly tested, inappropriate state of fuel storage tanks and pumps, suitable alarming signs, inappropriate entrance and exit ways, in appropriate reception system.	8
3	Unsuitable Earth system not regularly tested, inappropriate state of fuel Storage tanks and pumps, suitable alarming signs, suitable entrance and exit ways, in appropriate reception system.	6
4	Suitable Earth system regularly tested, suitable state of fuel storage tanks and pumps, Suitable alarming signs, suitable entrance and exit ways, in appropriate reception system.	4
5	Suitable Earth system regularly tested, suitable state of fuel storage tanks and pumps, suitable alarming signs, suitable entrance and exit ways, suitable reception system.	1
6	Suitable Earth system and regularly tested, suitable state of fuel storage tanks and pumps, suitable alarming signs, suitable entrance and exit ways, suitable reception system, filling station is equipped with intranet central alarming system	5

Table 3. Decision-making factor and intensity ranking of fire

No	Description of Intensity	Rank
1	Residential houses or stockpiles of inflammable materials adjacent to the filling station, being located at high traffic avenue and the distance to fire station more than 2 km from gas station, fire extinguishing valve is further than 200m from gas station, the station has no automatic fire extinguishing system. The manual fire extinguishing system is not suitable (the official building is not equipped with automatic fire fighting system)	100
2	Residential houses adjacent to the gas station, being located at high traffic avenue and the distance to fire station more than 1-2 km, fire extinguishing valve is 100-200m from the gas station, the station has no automatic fire extinguishing system. The manual fire extinguishing system is not suitable (the official building is not equipped with automatic fire fighting system)	70
3	Residential houses adjacent to the filling station, being located at low traffic avenue and the distance to fire station more than 1-2 km from the filling station, fire valve 100-200m from filling station, the station has no automatic fire extinguishing system. The manual fire extinguishing system is not suitable (the official building is not equipped with automatic fire fighting system)	50
4	No residential houses adjacent to the filling station, being located in low traffic avenue, and the distance to fire station less than 1km from the filling station, fire valve is less than 100 m from the filling station, but is equipped with automatic fire extinguisher, manual fire extinguisher is suitable (the official building is not equipped with automatic fire extinguishing system)	25
5	No residential houses adjacent to the gas station, being located in low traffic avenue, fire station located in less than 1 km from the gas station, fire valve near the filling station, and the station is equipped with automatic fire extinguishing system, and suitable manual system (the official building is not equipped with automatic fire extinguishing system)	15
6	Being located at non-residential area in a low traffic avenue and the distance to the fire station is less than 1 km from the gas station, fire valve near the filling station equipped with suitable fire extinguisher. (The official building has an automatic fire extinguishing system)	5
7	Being located at a non-residential low traffic avenue and the distance of the fire extinguishing station to the filling station is less than 1 km. Fire extinguishing pipe near the station equipped with automatic and suitable manual fire extinguishing system (the official building has an automatic fire extinguishing system)	1

Table 4. Decision-making based on the obtained rate of risk

No	Rank	Description of probability of danger accordance	degree
1	<201	Urgent measures are required, corrective measures should be taken quickly	High
2	200-101	Corrections should be carried out	Moderate
3	>100	Monitoring and control are required	Low

One of the most important characteristics of fire risk assessment in filling station is the location of the station (whether within or outside residential areas), which in this case, 6 stations under the assessment fall outside of residential areas and the rest are within areas. Also from the land use point of view, 8 stations are in houses or factories and 43 are within residential areas. Other important characteristics of a filling station are its distance from fire station and fire extinguishing

pipe and the traffic flow characteristic, the results of which are given in Table 5.

Evaluation of fire extinguishing and alarming system showed that the only 4 equipped stations with automatic extinguishing system were owned by private sector and the others have manual extinguishing systems. It should be noted that only 28.8% of the stations have alarming system (35.3 % of privates, 20 % governmental). The

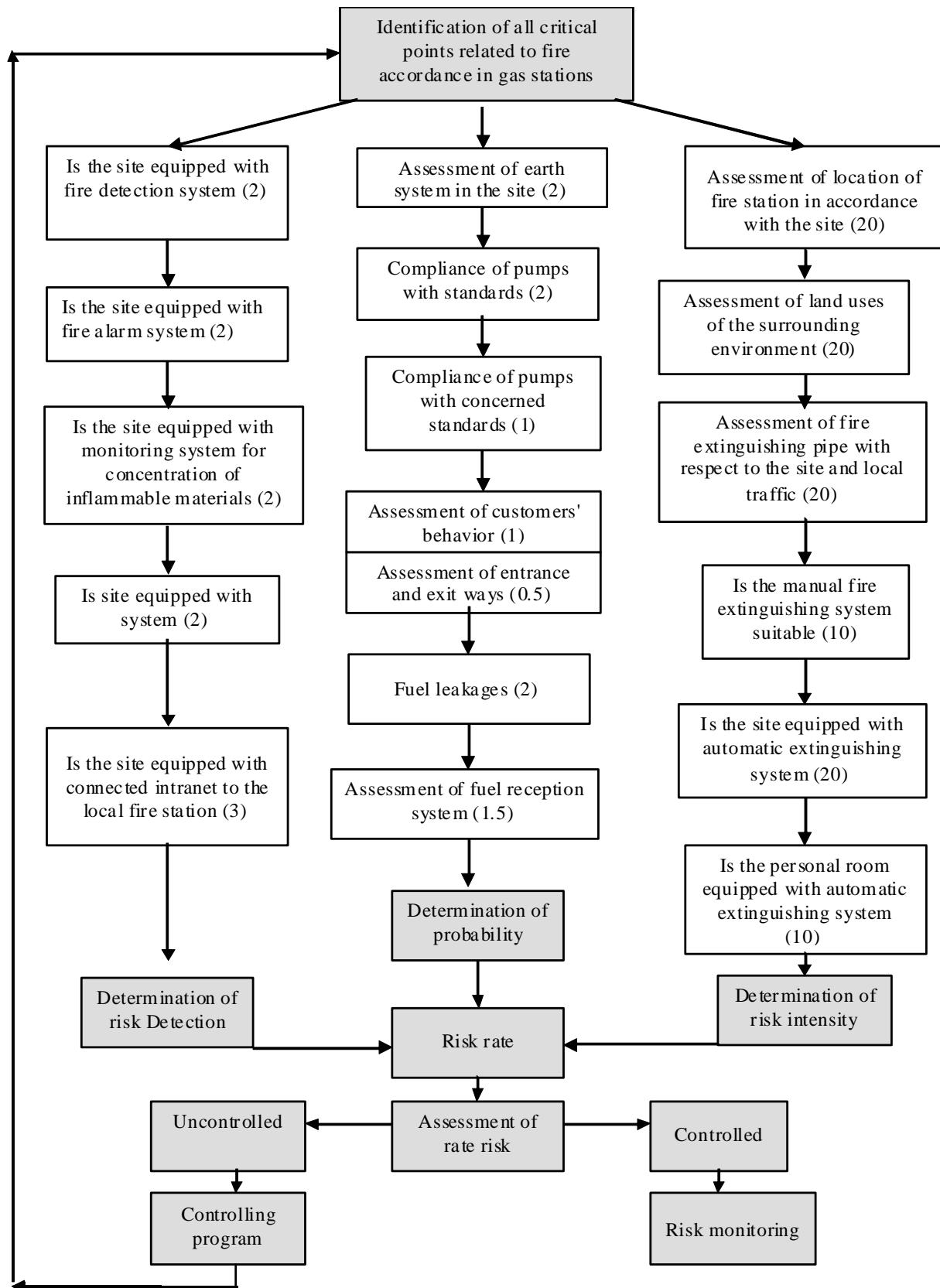


Fig.1. Decision-making process of proposed model of fire risk assessment in gas stations

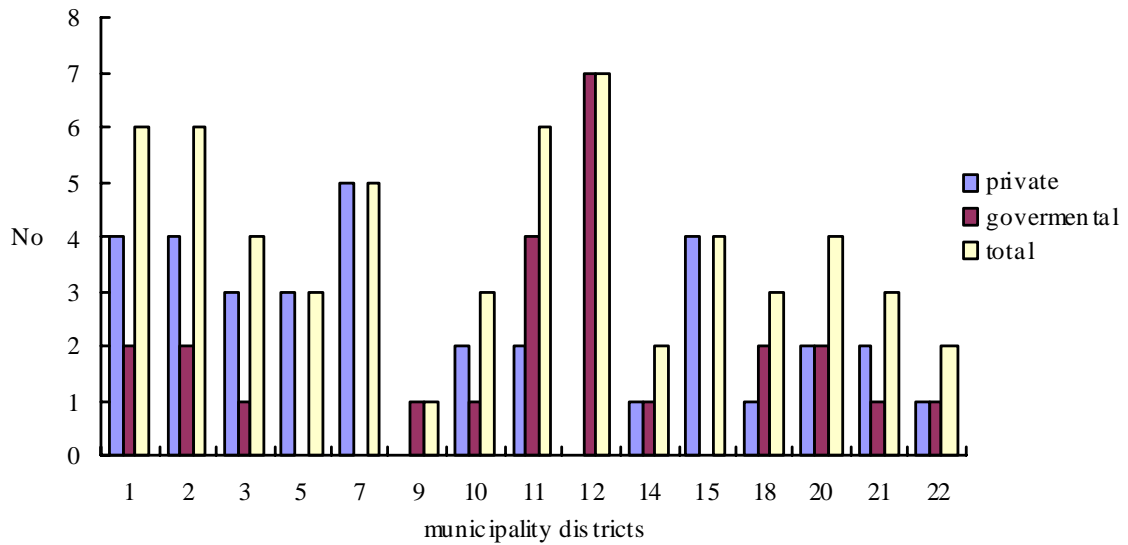


Fig. 2. Number of investigated gas stations in the municipality districts

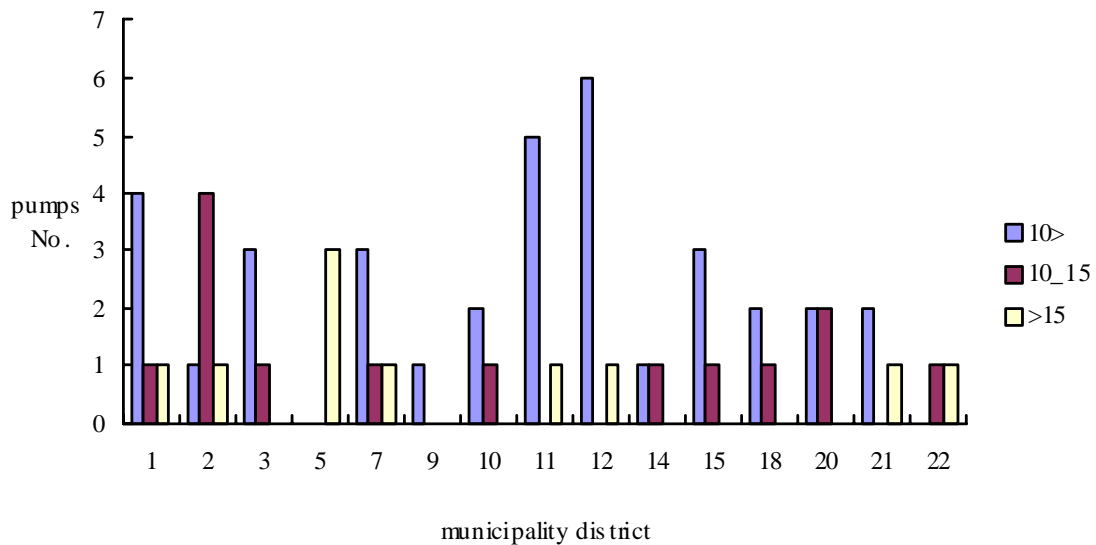


Fig. 5. Number of gas stations based on the number of pumps

Table 3. Number of gas filling station in high and low traffic areas and their distance from fire station and fire valve

Distance from the station (km)	high traffic load					Low traffic load						
	Distance from the fire valve(m)			Distance from the fire valve(m)			Distance from the station (km)			Distance from the fire valve(m)		
	<1	1-3	>3	<60	300-60	>300	<1	1-3	>3	<60	300-60	>300
6	33	8	25	14	8	0	9	3	5	2	5	

arrangement of manual fire extinguishing (84.8 % in private and 80 % in governmental stations) was proper. Only 19 % of the under study station has fire extinguishing system in the official buildings. Also, 52.8 % are equipped with automatic off key (64 % governmental and 47.1 % private).

Electrical system is appropriate in 84.7 % cases and inappropriate in others. With regard to the importance of earth system and its testing period, 79.6 % possessed an appropriate apparent state. Fig. 4 shows the results of earth system periods according to the state of ownership.

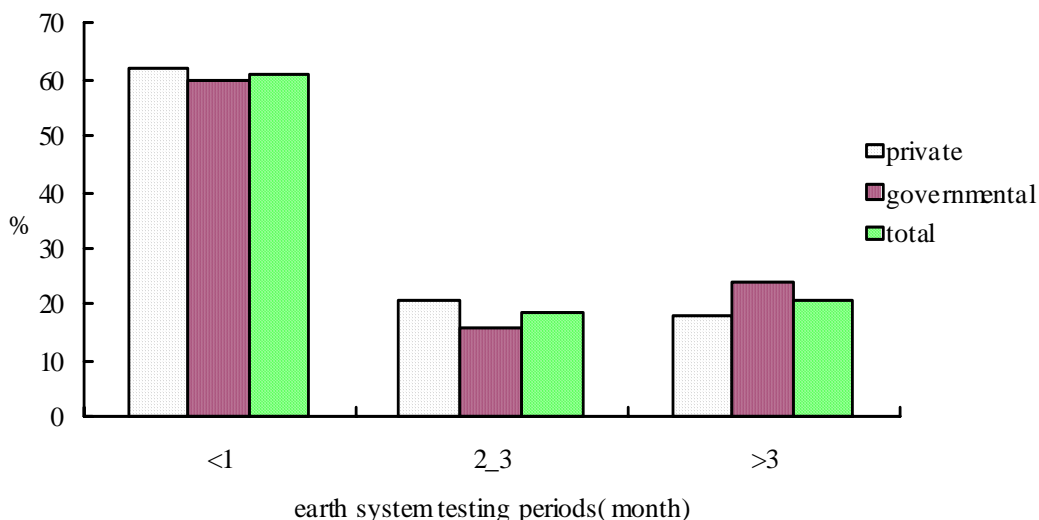


Fig. 4. Earth systems testing periods in gas stations divided to the state of ownership

Another important parameter in fire risk assessment is the state of fuel storage tanks. According to the obtained results, 41.7 % of governmental stations are not in good condition and they are not isolated by reinforced concrete. This applies to 11.8 % of private stations. The statistical analysis showed a significant variation in the relation of governmental and private gas stations ($p < 0.05$). Also, 28 % of governmental station does not have appropriate ventilations, which is 23.3% in private ones. Only 62.1 % sites are periodically tested for fuel leakages. 13.6 %

have desirable entrance and 85 % have desirable exit ways. 33.9 % have not been properly paved. Alarm signs are properly used in 72.9 % of the stations. Statistical results did not show a significant variation between governmental and private sites regarding the use of those signs ($p < 0.05$). The rate of risk way calculated for each gas filling station based on municipality districts separately is presented in Table 6. The results in Table 4 were evaluated based on the pattern presented in Table 2 and the achieved outcome is given in Fig. 5.

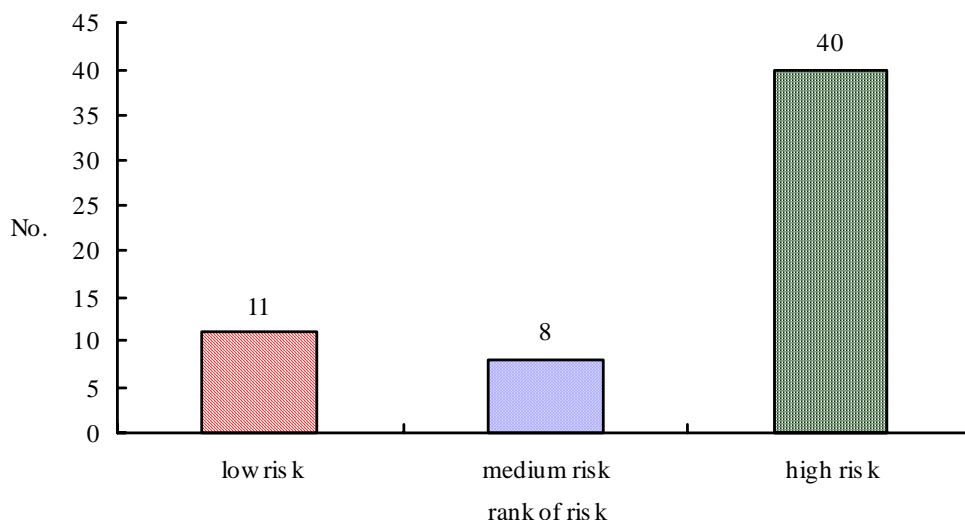


Fig. 5. Number of gas stations at each rank of risk based on Table 2

Table 6. Fire risk for gas stations according to the municipality districts

No	District	Intensity	Probability	detection	Risk	No	District	Intensity	Probability	detection	Risk
1	7	70	1.5	6	630	31	5	20	1.5	3	90
2	7	60	2.5	6	900	32	5	20	2.5	6	300
3	7	60	2.5	4	600	33	5	40	0.5	7	140
4	7	60	3.5	6	900	34	15	60	2.5	8	120
5	7	60	4.5	8	2150	35	15	60	1.5	0.5	45
6	3	50	1.5	2	150	36	15	30	1.5	2	47
7	3	60	1	8	480	37	15	30	2	6	360
8	3	70	0.5	2	70	38	12	70	1.5	6	630
9	20	60	2.5	1	150	39	12	70	1.5	6	630
10	20	60	6.5	8	3120	40	12	50	1.5	6	450
11	20	30	0.5	2	30	41	12	40	2	6	480
12	20	20	1	6	120	42	12	80	3.5	6	168
13	11	50	2.5	6	750	43	12	80	4	6	192
14	11	50	2.5	4	500	44	12	70	3.5	6	147
15	11	60	3	6	1080	45	1	9	3.5	10	315
16	9	80	4.5	8	2880	46	1	6	1.5	6	540
17	18	20	1.5	2	60	47	1	50	1.5	10	750
18	18	20	4.5	6	540	48	1	60	4.5	10	150
19	18	50	0.5	10	250	49	1	60	2.5	6	900
20	10	50	5	10	2500	50	1	50	2.5	8	100
21	10	60	4	8	1920	51	21	40	0.5	4	80
22	22	10	2.5	6	150	52	21	40	0.5	4	80
23	22	20	3.5	8	560	53	11	70	8	8	448
24	22	50	2.5	6	750	54	11	7	10	8	560
25	2	60	1	6	360	55	10	6	9	8	432
26	2	60	0.5	6	180	56	11	60	8.5	8	408
27	2	50	0.5	4	100	57	14	60	1	4	240
28	2	60	0.5	2	60	58	14	50	1	8	400
29	2	60	0.5	2	60	59	3	70	0.5	4	140
30	2	50	1.5	6	450						

Most of the personal of gas stations have been trained for extinguishing fire, but only 5% of them have been trained for crisis management and maneuvers have been hold for preparedness against emergency conditions. For all gas filling station concept scenarios, significant hazard and significant risk were identified. These scenarios need to be analyzed in more detail to obtain a more accurate estimation of actual risk (Sandra *et al.*, 2003). In this study, all of effective parameters in gas filling stations risks were identified and assessed (Karakitsios *et al.*, 2007). The method applied in this study is similar to that of Thivel who used FMEA method in his study (Thivel *et al.*, 2008).

With regard to the obtained results, it is obvious that Tehran's gas filling stations are not in good states and are exposed to high risk of fire. More than 68 % of the stations are in critical conditions and quick reconstructions are needed. The results also showed that more than 89 % of the stations are located in residential areas which will cause irreversible damages if explosions or fires occur. Nearly 80 % of the stations are situated on the streets with a high load of traffic, which in turn can result in challenges in delay arrival of fire fighters to the place. More than 30 % of fuel storage tanks are not even favorable in appearance and the standards have not been met in their construction. This is potentially very hazardous with regard to the materials stored and it can increase the risk in case of problems. Of course, it is noteworthy that the private sites are in better conditions compared to the governmental ones due to financial and management resources. More than 30 % of fuel storage tanks are not even favorable in appearance and the standards have not been met in their construction. This is potentially very hazardous with regard to the materials stored and it can increase the risk in case of problem. More than 80 % of the stations are not equipped with proper automatic alarming and extinguishing systems. Manual extinguishing systems are of a good quantity and quality, but their arrangements are not desirable which should be rearranged to bring up their best performance. Electrical networks are perfect and do not need any further correction. Earth systems are regularly tested and its integrity is ensured. Regarding the importance

of this issue all the stations are expected to have no problem unless the testing dates are from several mounts before.

CONCLUSION

This study showed that most of the stations do not have proper entrance and exit pathways and also speed control barriers will increase the probability of fire resulting from car accidents. Alarming signs are adequately used in majority of the stations, which indicates the safety culture among the managers and the owner of these sites. Due to lack of information and monitoring system, safety issues are limited to these signs. With regard to leakage finding system, all the gas filling station must be equipped with the system in order to detect the leakage and stop the occurrence of fire before it really happens.

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