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Industrial Fire Brigade Emergency Response Time Parameters for Oil & Gas Facility

Zamal Bujang[1], Mohamad Ibrani Shahrimin Adam Assim[2], Nor Mariah Adam[3], Omar Faruqi Marzuki[4], Shafinah Kamarudin[5]
[1,2]Department of Social Science and Management, Faculty of Humanities, Management and Science, Universiti Putra Malaysia Bintulu Campus, Sarawak, [3,4]Department of Science and Technology, Faculty of Humanities, Management and Science, Universiti Putra Malaysia Bintulu Campus, Sarawak, [5]Faculty of Computer Science and Information Technology
Corresponding Author's Email: zamalbujang@gmail.com

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Abstract
Emergency response operations are essential activities in the oil and gas facility. As an incident in an oil and gas facility area can have a considerable economic and social impact, a response to such an incident must be provided in a very short time. An essential part of every plant emergency organization should be the industrial fire brigade. In relation to the emergency management process, the estimation of response time plays a very crucial role. Response time is the time required by the emergency services, particularly for the industrial fire brigade, to reach the incident point after getting incident information. The use of parameters plays an important role in the successful implementation of emergency response. The decisions for such emergency responses should consider the available emergency resources and other factors such as emergency responders' competency, drill and exercise, fire protection and fire detection system, and the characteristics of surrounding affected oil and gas facilities. This case study considered configuration emergency response time parameters for an industrial fire brigade at an oil and gas facility. Therefore, to predict the response time, consideration must be given to the characteristics of emergency response parameters, their effectiveness, and their efficiency. Having this process will enable the company to improve emergency preparedness and response management. The results obtained from the analysis show that the framework is applicable to designing the response to incident conditions. It is expected that the framework would help in better resource allocation and efficient response to incidents in industrial areas.
Keywords: Emergency Response Time, Industrial Fire Brigade, Emergency Responders.

Introduction

Integrating industrial fire brigade into response time strategies, by identifying the emergency response parameters, strengthening risk assessment and disaster/emergency prevention, will be critical and the ultimate purpose of emergency management. The protection of life, preserve the environment and protect property and the economy is of paramount importance. In the broadest sense, emergency management raises the understanding of risks and contributes to a safer oil and gas facility. Several major fires in 2005 highlighted issues that related industrial fire brigades. The first was the BP refinery in Texas City, Texas, on March 23, 2005. Explosions and fires killed 15 people and injured another 180, resulted in financial losses exceeding $1.5 billion and forced 43,000 people into shelters. The second was the Buncefield oil depot fire in Hertfordshire, U.K., on Dec. 11, 2005. It was the largest fire in Europe since the Second World War and took four days to control. Both cases highlight the requirements for industrial fire brigades to be trained and competent as well as able to work harmoniously with their public counterparts. This research is to understand how the operational effectiveness of the emergency response time by the industrial fire brigade can be improved by applying applicable configurable parameters. Emergency response time is controlled by different characteristics/factors; this pilot study will identify, analyze and determine the degree of their consequence and effect on the overall response time.

This research begins with a case study involving Industrial Fire Brigade for oil and gas facility located in Bintulu, Sarawak, Malaysia. The research objective is achieved by answering two questions

1. What are the industrial fire brigade parameters required to reduce emergency response time for an oil and gas facility and the direct effect on response time improvement?
2. Could an emergency fire services interventions being identified, modelled and implemented that can significantly and effectively improve response time.?

Problem Statement

According to IBISWorld, "Global Oil & Gas Exploration & Production Industry - Market Research Report." The oil and gas industry are one of the largest sectors in the world in terms of dollar value, generating an estimated $5 trillion in global revenue as of 2022. Oil is crucial to the global economic framework, impacting everything from transportation to heating and electricity to industrial production and manufacturing. The

A large and valuable facility located in an oil and gas facility may require an organized, sophisticated fire brigade. A fire brigade should be organized to meet the needs of a specific facility based on location, the response time of local fire departments, and the facility's value. NFPA 600: Industrial Fire Brigades is a good resource for organizing a fire brigade. NFPA currently has a Technical Committee updating the Industrial Fire Brigades' Professional Qualifications standard. In addition, the International Society of Fire Service Instructors (ISFSI) publishes some outstanding performance criteria for industrial fire brigades.

When incidents occur, the industrial fire brigade's role is to perform the initial fire attack and co-ordinate responders from outside. The community response is to the gate and the industrial brigade retains incident command. In some more significant industrial regions, there are mutual-aid agreements among industrial brigades. This is an effective use of these valuable resources but requires close communication among outside municipal fire departments and the industrial brigades and a better understanding by all parties of industrial firefighting standards. NFPA 1710 section 4.1.2.1 states that a fire department shall arrive within four minutes after receiving the fire alarm 90% of the response times. The National Fire

Protection Agency (NFPA) recommends a two-minute turnout time. NFPA 1710 (2004), defined the term "response time," is measured as the total travel time between the fire units leaving the station and arriving at the scene. When benchmarking a fire & rescue service's response time, it is usually compared to a standard response time. The current the plant fire brigade response performance can provide a minimum of five responders to this fire area in full turnout gear within 5–10 min. The public fire department response time is approximately 20–25 min. A delayed response can have the life-threatening, reputation, and economic consequences that may otherwise have been avoided.

Mattsson & Juas (1997) studied and found that responses delayed by as little as five minutes can allow overall damage to increase by 97 percent for tightly coupled events such as structural fires, road accidents, or drowning cases. Murray et al (2020) on Fire Department Response Capability, Performance, and System Resilience during Urban Fire Forum that in 2015 NFPA reported that fire departments responded to 1,345,500 fires, more than 21.5 million EMS calls, 2.5 million false alarms, 1.5 million mutual aid responses, 442,000 hazardous materials responses, and more than six million other responses. In 2016, NFPA reported that there were 1,342,000 fires reported in the United States. These fires caused 3,390 civilian deaths, 14,650 civilian injuries, and $10.6 billion in property damage. Of all the fires in the NFPA dataset, 475,500 were structure fires, causing 2,950 civilian deaths, 12,775 civilian injuries, and $7.9 billion in property damage. NFPA also reported that 173,000 were vehicle fires, causing 280 civilian fire deaths, 1,075 civilian fire injuries, and $933 million in property damage

Literature Review

The National Fire Protection Association (NFPA) is a global self-funded non-profit organization, established in 1896, devoted to eliminating death, injury, property and economic loss due to fire, electrical and related hazards. NFPA delivers information and knowledge through more than 300 consensus codes and standards, research, training, education, outreach and advocacy; and by partnering with others who share an interest. For this research the following standards been used and referred.

i. NFPA 600: Standard on Facility Fire Brigade.

NFPA Standard 600 details the organization of the fire brigade with respect to standard operation procedures (SOPs), and classifies the primary function of the fire brigade as an guidance and requirements for brigades that are assigned for multiples fire emergencies and also an Incident Management system that defined the different roles.

ii. NFPA 1081: Standard for Industrial Fire Brigades Member Professional Qualifications.

It was established as a minimum job performance requirement necessary to perform the duties as a member of an organized industrial fire brigade providing services at a specific facility or site.

iii. NFPA 1710: Standard for the Organization and Deployment of Fire Suppression Operations, Emergency Medical Operations, and Special Operations to the Public by Career Fire Departments.

This standard specifies requirements for effective and efficient organization and deployment of fire suppression operations, emergency medical operations, and special operations to the public by career fire departments to protect citizens and the occupational safety and health of fire department employees.

iv. NFPA 1600: Standard on Continuity, Emergency and Crisis Management.

The standard covers the key elements required for effective emergency management and business continuity. It addresses topics such as program planning, implementation, execution, and training Oil and Gas Conservation Commission, Practice and Procedure, Code of Colorado Regulations, 2 CCR 404-1, February 2013, regulation defined that Oil and Gas Facility shall mean equipment or improvements used or installed at an oil and gas location for the exploration, production, withdrawal, gathering, treatment, or processing of oil or natural gas. ABB Oil and Gas Production Handbook described that the oil and gas industry facilities and systems are broadly defined, according to their use in the oil and gas industry production stream:

- Exploration
  Includes prospecting, seismic and drilling activities that take place before the development of a field is finally decided.
- Upstream
  Typically refers to all facilities for production and stabilization of oil and gas. The reservoir and drilling community often uses upstream for the wellhead, well, completion and reservoir only, and downstream of the wellhead as production or processing. Exploration and upstream/production together are referred to as E&P.
- Midstream
  Broadly defined as gas treatment, LNG production and regasification plants, and oil and gas pipeline systems.
- Refining
  Where oil and condensates are processed into marketable products with defined specifications such as gasoline, diesel or feedstock for the petrochemical industry. Refinery offsites such as tank storage and distribution terminals are included in this segment or may be part of a separate distribution's operation.
- Petrochemical
  These products are chemical products where the main feedstock is hydrocarbons.

This NFPA 1600 standard provides recommendations for the minimum criteria for emergency management planning for both private and public organizations. Specifically, this standard recommends the following five core planning areas (NFPA 2002b, 4-7):

- **Assessment and mitigation:** the types of hazards that make the organization vulnerable to emergencies and steps that can be taken to prevent or reduce the effects of the emergency
- **Preparedness:** the activities, programs, and systems developed prior to an emergency that are used to support the facility's response program
- **Response:** the activities that will help to stabilize and control the emergency
- **Recovery:** the activities that will help to return the facility to a functional status
- **Training and evaluation:** training activities based on duties and responsibilities and an overall review and evaluation of the plan on a regular basis.

According to Office for Outer Space Affairs UN-SPIDER Knowledge Portal that an emergency Department of Humanitarian Affairs/United Nations Disaster Relief Office - United Nations Development Programme (1992), defined an emergency might be regarded as a particular type (or sub-set) of a disaster. "Emergency" suggests an intense period and level of urgency. An emergency is bound by a specific period in which lives and essential property are immediately at risk. Britton (2019) cited that emergency management functions are increasingly connected to environmental stewardship, community planning and sustainable development issues. Emergency management is being relocated within a wider framework, or so it seems. Recent efforts have suggested that it is, for example, an integral part of community decision-making.

A fire brigade utilizes manual firefighting methods for fire suppression. This may be considered the entire fire safety effort available to suppress a fire in its early stages. The first objective is to suppress a fire in the event of impairment of automatic protection and to provide extinguishment capabilities where automatic protection is not provided. The point has been demonstrated that each facility will organize a fire brigade differently. Manpower requirements for the fire brigade should be established. Anticipated fires should be postulated, and the number of persons determined from anticipated tasks required for fire suppression. Management must decide how it will support the fire brigade in all areas, particularly equipment and training. The fire brigade organizational structure should be broken into squads. Special duties should be assigned to specific squads (such as ensuring that control valves are open, or fire pumps are running). In addition to extinguishing fires, individual squads are responsible for salvaging and handling electrical problems. In smaller organizations, multiple functions can be assigned to one squad. Cragg (1993) outlines the responsibilities and qualifications for fire brigade members and leaders. The NFPA 600 standard covers the minimum requirements for organizing, operating, training, and equipping industrial fire brigades. Additionally, the standard covers minimum requirements for brigade members. The fire brigade's responsibilities are to

- Supervise department fire evacuation drills
- Operate firefighting equipment (e.g., extinguishers, hoses)
- Provide emergency scene first aid and CPR if needed
- Conduct inspections of particular departments
- Implement emergency shutdown procedures

NFPA 1081: Standard for Industrial Fire Brigade Member Qualifications was prepared by the technical committee and the job performance requirements for the industrial fire brigade operations levels are defined in *NFPA 1600*. Since the 2012 edition of *NFPA 1081*, the committee has added time requirements of 2 minutes that relate to clothing and the activation of SCBA and PASS devices. In addition, a section has been added that addresses the limits and responsibilities of industrial fire brigade members to be consistent with NFPA 600*:* Standard on Facility Fire Brigades.

NFPA 600 Standard for Industrial Fire Brigades 2005 Edition should be the overall requirement should a plant or facility from the fire brigade. It covers the need for a site-specific evaluation of the hazards and developing an organizational statement of response duties. It requires a balanced application of the principles found within NFPA 1500 to protect brigade members. It also requires the establishment of an incident-management system as per NFPA 1581. This helps to ensure a standard level of understanding among responders.

Additionally, all firefighting personnel should carry out their duties to NFPA 1081 Standard on Industrial Fire Brigade Member Professional Qualifications 2007 Edition. The rest of the equipment apparatus standards are all to NFPA or other industry standards familiar to municipal responders. Therefore, all municipal fire services responding to support industrial brigades must understand these standards.

Fitch (2005) cited the response time norms implemented in various countries. These included North America, which adopted the 8:59 benchmark in urban areas, 15 minutes in rural areas, and 30 minutes in wilderness areas. It was indicated that these should be achieved for 90% of the life-threatening emergency cases. The United Kingdom has had an established national standard since 2001 for both urban and rural areas for life-threatening cases. This standard includes achieving a response time of eight minutes with 75% compliance, of which 95% must be within 14 minutes in urban areas and within 19 minutes in rural areas. Response times in Australia are measured at five, 10, and 15-minute intervals. It was reported that 50% of the cases are responded to within 10 minutes for both rural and urban areas. Ahmed Jarallah (2015) stated that on August 5, 2004, NFPA-1710 established specific response time objectives for fire suppression services. According to the NFPA, the term "response time" is measured as the total amount of travel time between the fire units leaving the station and arriving at the scene. NFPA-1710 section 4.1.2.1 states that a fire department shall arrive within four minutes after receiving the fire alarm 90% of the response times.

Mattsson and Juas (1997) studied and found that responses delayed by as little as five minutes can allow overall damage to increase by 97-percent for tightly coupled events such as structural fires, road accidents, or drowning cases. Similarly, the arrival of emergency responders in five minutes instead of seven can nearly double the probability of survival in heart attack victims. Hong Kong adopted what is known as a performance pledge which involves arriving within 12 minutes for 92% of all cases. The same response commitment has been made to both emergency and non-emergency cases. According to Kobusingye *et al.* (2005), in Monterrey, Mexico, the average response time achieved was 10 minutes, while in Hanoi, Viet Nam the recorded average response was 30 minutes. A descriptive study conducted by Langhelle *et al.* (2004) in Nordic countries reported a response time average of fewer than five minutes to cases categorized as immediate life-threatening in Copenhagen in Denmark. The Norwegian government required response time for patients in remote areas was 45 minutes and using predominantly service, rotor-wing ambulances operated by physicians.

London recently reported a deterioration in response times of up to 12% over a period of 12 months as compared to the target of eight minutes and with late arrivals to 42% of critically ill patients (Daily Mail, 2016). This clearly indicates that, as predicted by Blackwell and Kaufman (2002) and Pons and Markovchick (2002), the sustainability of the eight-minute target is unrealistic.

Finlayson (2017) reported, The South African national response time standard for urban areas is less than 15 minutes and less than 40 minutes for rural areas. The KZN public EMS uses this benchmark to measure their responses to priority one (red code) cases in both urban and rural areas (KwaZulu-Natal Department of Health 2004. A critical component of emergency response is the time taken to respond, which has been identified as a measure of emergency performance Al-Ghamdi (2002), and Pons et al (2002). A few scholars have asserted that performance measurement is recognized as an index of output or production. Because the time taken to respond by firefighting teams is a form of work output, the response time is clearly a form of performance measurement. Kolesar and Walker (1979) studied the relationship between the time and distances of 2000 incidents attended by 15 units within New York City at different times of the day. This study found that for short distances, travel time increased with the square root of the distance and that the travel time increased linearly for long travel distances. Stein (2014) cited that No standard or norm has been cited for non-priority cases in South Africa.

Stephen (2011) defined the operational timeframe for the fire service begins with their arrival on the scene and ends when the fire is under control (Figure 3). To compare the modern and legacy fire environment, it is important to examine the time prior to fire department arrival. The time t1, depends upon several factors such as when the fire is detected after initiation and the time to call for fire service assistance. This time can vary greatly depending on the source of ignition, item ignited, presence of occupants, fire protection devices and many other factors. The time t2, is the time for the 911 operator to call the appropriate fire station to respond. The US national standard NFPA 1221 defines the maximum value for t2 as 60 s. The time t3 is the time it takes for the firefighters to get onto the fire apparatus and respond. As per NFPA 1710 this equals 60 s to begin the response. The time t4 is the time it takes for the firefighters to drive to the scene of the fire. Following NFPA 1710, the goal for fire emergency response is to arrive at the scene within 4 min after the 911 call is made. That is, t2 + t3 + t4 £ 6 min. Following NFPA 1720, the goal for fire emergency response is to arrive at the scene within 9 min in an urban area, 10 min in a suburban area, 14 min in a rural area, and directly related to the driving distance for remote areas greater than 8 miles from the closest fire station. Therefore t2 + t3 + t4 ≤ 11 min to 16 min. Fire Research Series (2011) stated that some international comparisons of fire department response times are available. In 2006, the average response time to dwelling fires in England was 6.5 min. A report comparing residential fire safety in several countries' states.

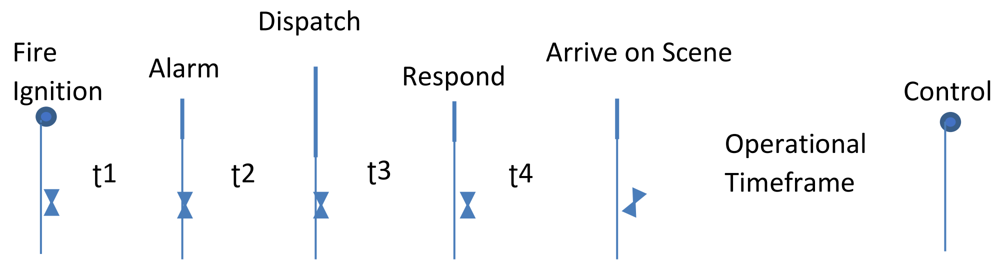
According to Schaenman (2007), Response time goals in Sweden and Norway are more lenient than in the United States. The Scandinavian nations require the first responding unit to arrive in 10 min, versus a goal of 6 min in the typical United States city. A report written by a German Fire Officer in 2004 examined response times in Europe by contacting country officials and asking them questions about their good response times and conducting an internet search. Stiegel J (2004), stated that any countries such as Denmark, France, Greece, Ireland, Norway, and Sweden had sufficient urban response times of 10 min and response times to suburban or rural areas of 15 min to 30 min. For this research, operation effectiveness is defined as any kind of practice that allows a fire station to maximize its ability to meet all regulations and societal expectations as well as maximize its ability to provide emergency aid to the community it serves. The NFPA require first responders be timely in their response to an emergency call. The NFPA defines Total Response Time as the time interval from the receipt of the alarm at the primary station of responsibility to when the first emergency response personal begins initiating action or intervening to control the incident. According to NFPA, to be accredited, all fire stations must measure the Total Response Time and meet a minimum level of service. For nearly every emergency type, the Total Response Time for the first arriving company is set to seven minutes. NFPA 1710 more specifically details the goals for each of the parts of Total Response Time: two minutes for turnout, and five minutes for travel.

Table 1: Research and Literature Review on Response Time Parameters

Year	Researcher/s	Perspective	Title	Parameter
2018	Tyler et al.,	Alarm Notification	Statistical Analysis of Fire Department Response Times and Effects on Fire Outcomes in the United States.	alarm time, arrival time, Incident controlled.
2017	Keegan et al.	Capability & Procedural	Improving Fire Station Turnout Time.	Configurational, Procedural, Behavioral Factors,
2016	Benjamin M Taylor	Physical	Spatial modelling of emergency service response times	Location of fire station, Baseline hazard, cumulative hazard, Relative risk,
2016	Mainak Bandyopadhyay et al.	Route	Development of agent based model for predicting emergency response time.	Route selection behavior and driving speed based on the proximity characteristics of road segment,
2015	Ahmed Jarallah Al-Jarallah	Physical and Non Physical Factors.	Analysis of Characteristics and Factors Influencing Fire Incidents Response Times in Urban Areas in Saudi Arabia: Case Study of Dammam City.	Land zones, Fire Station location, population and accessibility, Time, Traffic Low, Administration and Socio-Culture
2015	Daniel S. et al.	Capability	Improving Fire Department Turnout Times: Training v. Sanctions in a High Public Service Motivation Environment.	Organizational strategies (training v. policy enforcement with sanctions), Training (Competency), Station & Control Variables
2015	Soufiene Djahel et al.,	Traffic Management and Procedure	Reducing Emergency Services Response Time in Smart Cities: An Advanced Adaptive and Fuzzy Approach.	Traffic Management System, Speed Limit Change, Emergency Response Plan.
2013	Ed Claridge et al.	Notification & Speed	New Zealand fire service response times to structure fires.	Times for receipt of information, for dispatch, fire-fighter response, Fire appliance response speeds and distance relationship, Minimum

				and maximum response speeds
1998	Vincent L. Kemp	Human Elements & Information	A Study To Determine Reflex Time Of Responding Emergency Personnel For The Alhambra Fire Department.	Reflex time of responding personnel, Acceptable reflex time standard, incident information, Individual Responders
1979	Lawrence M. Pietrzak.	Vehicle Performance	The Effect of Fire Engine Road Performance on Alarm Response Travel Times.	Travel Time Model (road and vehicle related factors), Fire Engines Performance Characteristics

Table 2: Time Correlation with Temperature and Sequence Of Events



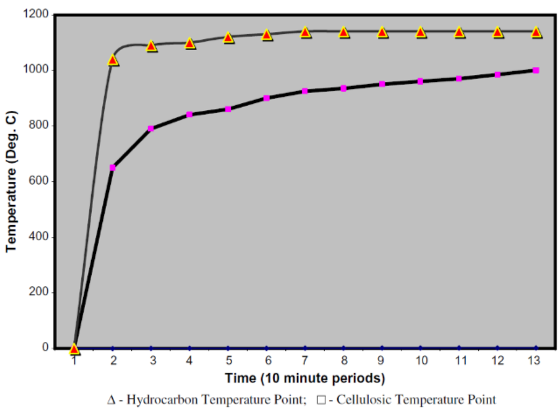


Figure 1: Time temperature curves for hydrocarbon versus cellulosic fires. (Source: Handbook of Fire and Explosion Protection Engineering Principles)

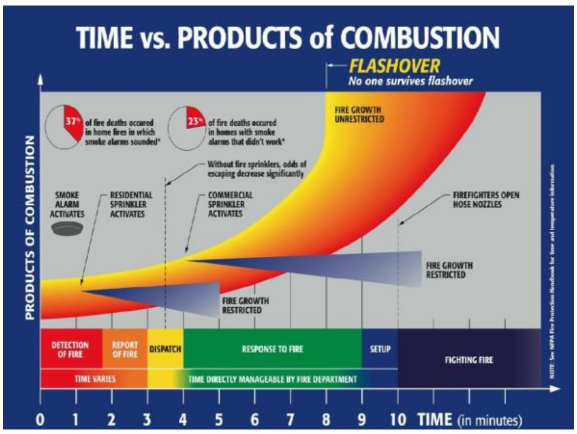


Figure 2: Fire Growth Over Time And Sequence Of Events That May Occur From Ignition To Suppression. (Source: SFPE Handbook 2005)

From the Table 2, Figures 1 and 2 above, it was time correlation with temperature and sequence of events how the Fire service timeline shall response within the period of times.

Methodology

The following data have been collected to achieve the goal of this 'Pilot Test Research' paper. A descriptive causal-comparative method and semi-structured interview technique were used as it attempts to determine the parameters to reduce emergency response time and the standard time required.

A Pilot Test was carried out, and the semi-structured interview technique was used to obtain and synthesize the opinions of experts from the expert's opinion / subject matter expert (SME) sector in Malaysia, particularly those who involved in the managing of emergencies for Oil and Gas Industry and 20 oil and gas facilities emergency responders' respondents.

Five (5) experts who had been working for a minimum of 15 years and were currently at the management level and operational level in their organizations. This subject matter expert (SME) from various background and sectors were interviewed using a semi-structured interview schedule. The interviewees were selected based on an assessment of their importance for the management of emergency preparedness and response. Another 20 respondents were those who were involved and appointed to the emergency response team. The questions embraced the following topics

Table 3: Research Survey questionnaires (Pilot Test)

Name & Designation *Please list and describe the parameters required to reduce emergency response time for Industrial Fire Brigade.* *Form your opinion what are the ideal of 'Response Time' (in minute)?*

Findings and Recommendation

Table 4 – Table 10 illustrates how the Pilot Test Research Survey findings from five (5) expert's opinion / subject matter expert (SME) and randomly twenty (20) selected emergency responder's (ERT/emergency response team) perspectives, it correlation with parameter to reduce emergency response time for industrial fire brigade. This study suggests that the Industrial Fire Brigade Variable Parameters Required to Reduce Emergency Response Time is complex, dynamic, and structured.

This findings study suggests that the Top 4 parameters/variables to be categorized / characterized based on the following priority:

Table 4: *Subject Matter Experts and Emergency Responder Pilot Survey Research Summary Analysis.*

Parameters/Variables

Subject Matter Expert/ Expert Opinion	Emergency Responder
Fire vehicle driver's competency	Drill / Exercise
Automatic Fire Alarm System / Detection System	Emergency Responder Competency
Fire station numbers & location	Standard Operating Procedure (SOP)/Guideline to response
Drill / Exercise	Layout Plan / Mapping

Ideal of Response Time (min)

Subject Matter Expert/ Expert Opinion	Emergency Responder

# of SME	Ideal Time (min)
n = 2	5 min
n = 1	7 min
n = 1	10 min
n = 1	12 min
Total=5	

# of Respondent	Ideal Time (min)
n = 1	3 min
n = 8	5 min
n = 7	7 min
n = 2	10 min
n = 1	12 min
n = 1	15 min
Total=20	

Table 5: Expert Opinion on Industrial Fire Brigade Variable Parameters Required to Reduce Emergency Response Time

	Variables														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	
Subject Matter Expert	Fire station numbers & location	Physical Road condition	Traffic condition	Fire vehicle condition	Fire vehicle's competency	Road user awareness and cooperation	Incident Notification & Communication	Drill / Exercise	Access road	distance from station to emergency scene.	Emergency response vehicle speed limit	Standard Operating Procedure	Firefighting Response Strategy	Automatic Fire Alarm System / Detection System	Ideal of Response Time (min)
SME 1	•	•	•	•	•	•									5
SME 2	•				•		•	•							5
SME 3	•				•					•	•				10
SME 4				•	•		•					•		•	7
SME 5	•	•			•			•	•				•	•	12
Total	***4***	***2***	***1***	***2***	***5***	***1***	***2***	***2***	***1***	***1***	***1***	***1***	***1***	***2***	

Table 6: Expert Opinion on Industrial Fire Brigade Variable Parameters Required to Reduce Emergency Response Time

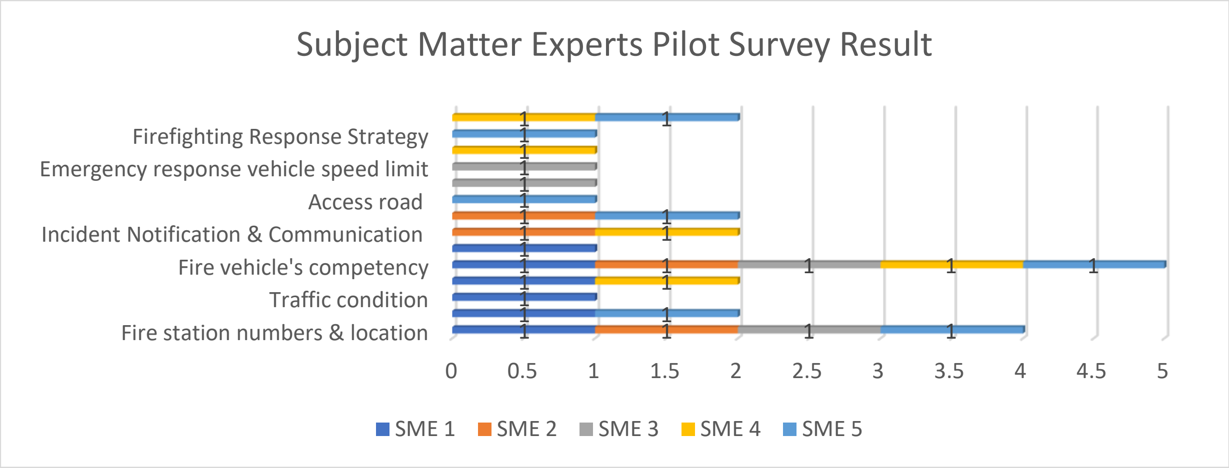


Table 7: Expert Opinion on ideal of Emergency Response Time

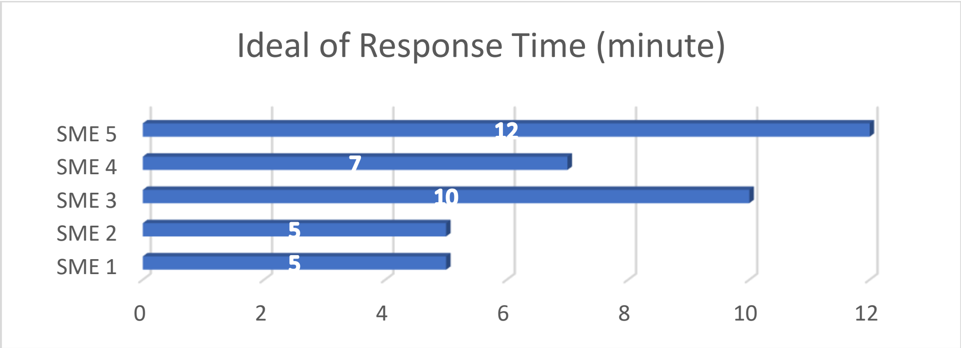


Table 5, 6 and 7 above defined the findings from five (5) subject matter experts pertaining to Industrial Fire Brigade Variable Parameters that required and recorded the ideal response time in between 5 -12 minutes.

Table 8: Emergency Responder Pilot Survey results on Industrial Fire Brigade Variable Parameters Required to Reduce Emergency Response Time

Respondent	Variables Emergency Responder Competency	Drill / Exercise	Access road	distance from station to emergency scene.	Emergency response vehicle speed limit	Incident notification	Standard Operating Procedure (SOP)/Guideline to response	Layout Plan / Mapping	Incident Action Plan (IAP)	***Ideal of Response Time(min)***
Respondent # 1	•	•					•			5
Respondent # 2	•	•	•							15
Respondent # 3			•	•	•					7
Respondent # 4	•						•			10
Respondent # 5	•		•				•			12
Respondent # 6	•	•				•			•	5
Respondent # 7	•				•		•	•		7
Respondent # 8		•						•		7
Respondent # 9	•	•	•			•	•	•		7
Respondent # 10		•		•				•	•	5
Respondent # 11		•				•	•	•		10
Respondent # 12	•	•					•		•	5
Respondent # 13	•	•				•		•		7
Respondent # 14		•	•			•		•		5
Respondent # 15	•	•		•			•		•	7
Respondent # 16	•					•		•		3
Respondent # 17		•				•	•	•		5
Respondent # 18	•	•		•				•	•	5
Respondent # 19		•				•	•		•	5
Respondent # 20	•	•				•	•		•	7
Total	***13***	***15***	***5***	***4***	***2***	***9***	***11***	***10***	***7***	

Table 9: Emergency Responder Pilot Survey results on Industrial Fire Brigade Variable Parameters Required to Reduce Emergency Response Time

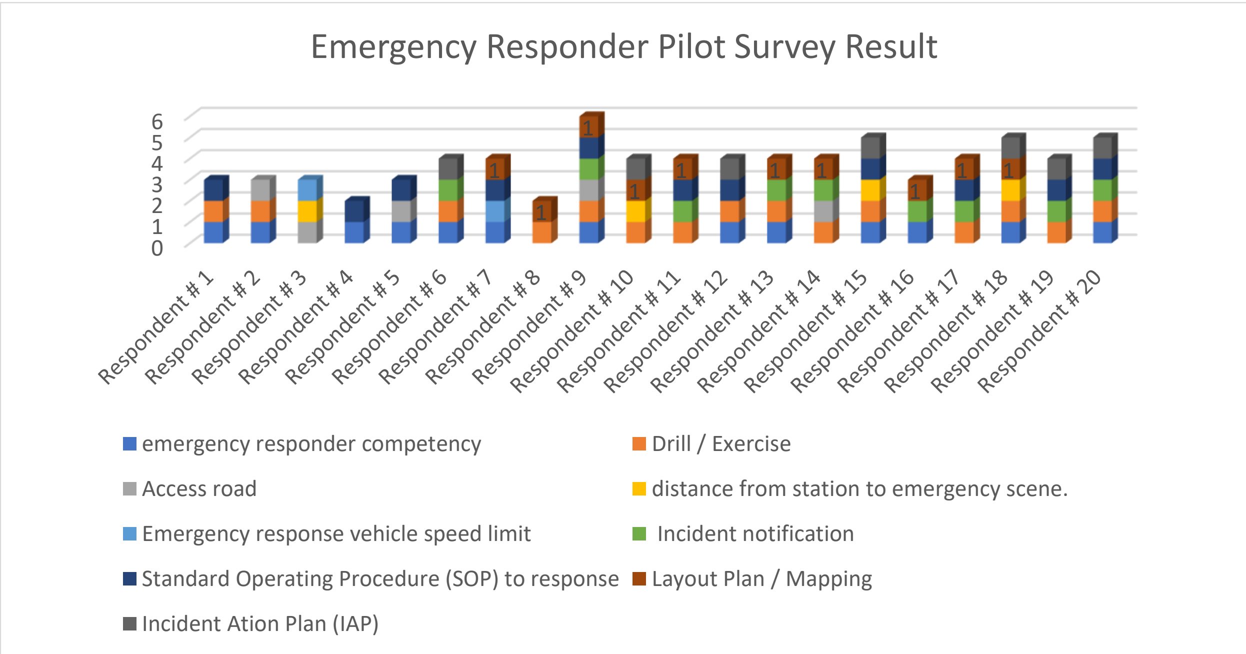


Table 10: Emergency Responder Pilot Survey on ideal of Emergency Response Time

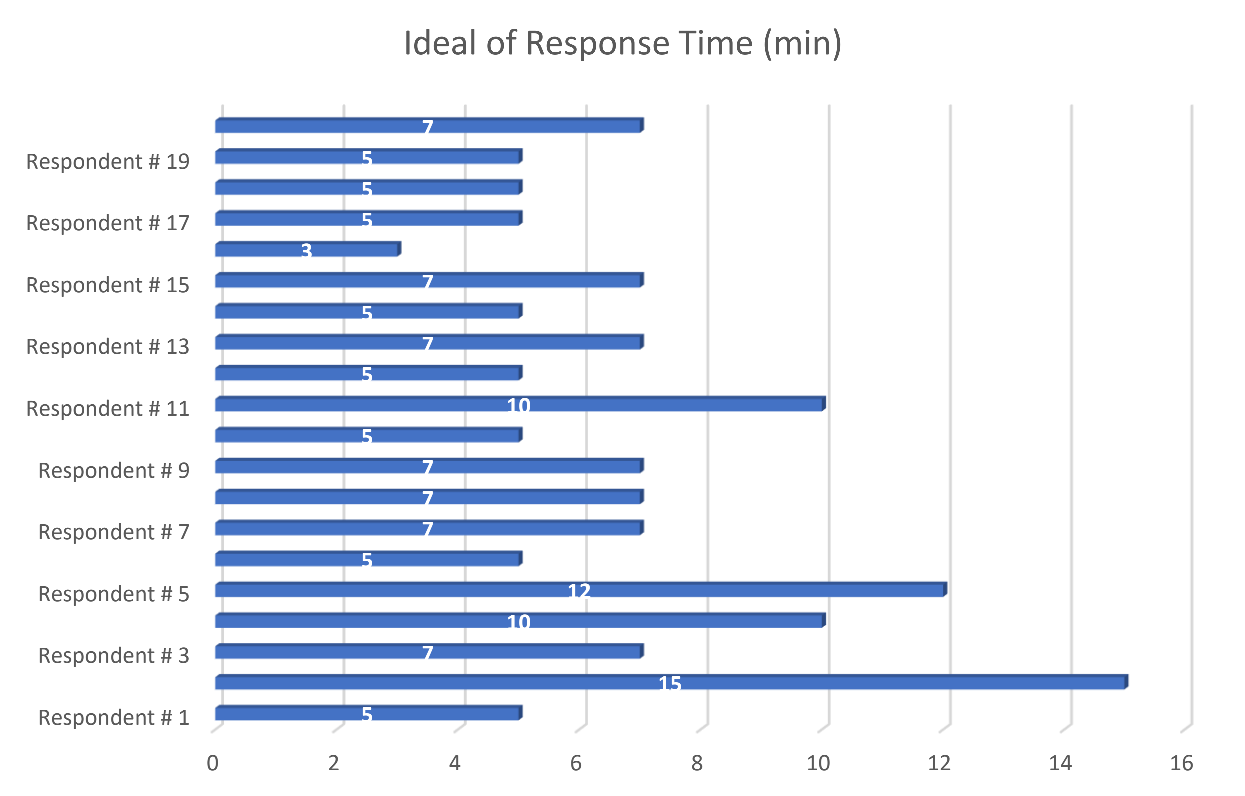


Table 8, 9 and 10 above defined the findings from twenty (20) emergency response team (ERT) as a frontline team pertaining to Industrial Fire Brigade Variable Parameters that required and recorded the ideal response time in between 3 -15 minutes.

Result

Based on semi-structured interviews from the five expert's opinions/subject matter experts (SME) and 20 respondents of the emergency responders from the oil and gas industry, it can summarize the similar findings on the top 5 following parameters:

i. Fire vehicle driver's competency & Emergency Responder Competency
ii. Automatic Fire Alarm System / Detection System.
iii. Fire station numbers & location and Layout Plan / Mapping
iv. Drill / Exercise
v. Standard Operating Procedure (SOP)/Guideline to response

i. Fire vehicle driver's competency & Emergency Responder Competency.

To provide the best services to oil and gas facilities, Industrial Fire Brigade must first understand what it is that they do. It shall come from the industrial fire brigade mission statement and from knowing what services they provide. This broad statement of what they do helps meet facilities' expectations and sets the tone for emergency services. The competency training must help the industrial fire brigade to meet and support this mission statement. Competency training aims to ensure that the industrial fire brigade can provide the best service. The overall goal in competency training should be to support the services through a safe and effective training program. This helps them provide those services safely, efficiently, and effectively. Competency is the ability to do something successfully or efficiently: Competency, in its purest sense is about whether a person can meet the minimum requirements of a job. Guang-li LI et al. (2014) defined the competency model of firefighters contains 5 factors:

a) Psychological quality: An excellent psychological quality is an important guarantee for qualifying firefighters for the position. The firefighters often implement fire extinguishing and rescue missions at high altitudes and poisonous, explosive or other dangerous environments.
b) Vocational skill: An excellent vocational skill is a premise for qualifying firefighters for the position. To reduce blind action and increase security, it is vital that firefighters reserve rich professional knowledge on firefighting, skilfully master emergency rescue skills and arm their minds with scientific theory.
c) Self-development: The extensive use of new technology and new energy sources makes the subjects of fire extinguishing and rescue more and more complex. So the, firefighters need to improve their working enthusiasm, keep learning and improve their innovative ability for any emergencies.
d) Professional accomplishment: Professional accomplishment is the key to qualifying firefighters for the position. The professional characteristics of the firefighting work (high load, high risk) determine that the firefighters must have these competencies of loyalty to and responsibility for the firefighting career, the confidence to overcome any disaster incidents, and the professional dedication and quality of bearing hardships.
e) Interpersonal cooperation: Every firefighter must be competent in team cooperation, communication and coordination because the fire extinguishing and rescue is a collective action. At the same time to improve their executive ability, the firefighters must unit as one to complete missions in a high-standard and high-quality way.

ii. Automatic Fire Alarm System / Detection System.

While fires can spread quickly, some other fires start because of heavy periods of dormant fires. In such cases, susceptible fire detection systems must be in place. Early detection is crucial in protecting first responders and other emergency response personnel as they combat fires. However, for fire detection systems to be ultimately effective, it should be integrated with alarm systems. Fire alarms play an important role in notifying facility inhabitants of a fire emergency. A signal to a central monitoring station that can either be on or off-site will determine the response time and emergency resources deployment. According to Zhigang Liu et al (2003), many new fire detection technologies developed over the last decade have strong potential to reduce false alarms, increase sensitivity and dynamic response to fire and improve fire safety. In recent years, fire detectors tend to be more intelligent in discriminating between fire and nonthreatening or deceptive conditions due to the introduction of artificial intelligence techniques, multiple sensors that combine smoke and thermal sensors or CO sensor are capable of overcoming the drawbacks of a single sensor in fire detection, and provide better fire detection by discriminating many nuisance sources and extend detection capability for many fire sources and providing the notification for the deployment of emergency services / industrial fire brigade.

iii. Fire station numbers & location and Layout Plan / Mapping.

Samira Bolouri et al (2020) examined a minimizing response time to accidents in big cities: a two-ranked level model for allocating fire stations in Tehran. The study focuses on demand allocation to fire stations at two ranked levels to determine the priorities of fire stations to service relevant demands. A Vector Assignment Ordered Median Problem (VAOMP), a new algorithms location–allocation model, was used that can allocate demands to facilities at several ranked levels based on the particular objective function. Genetic algorithms to minimize the arrival time from fire stations to demands, at two levels, at up to 5 min in the GIS environment. The optimum parameters for each algorithm were obtained through sensitivity analysis and the results of applying the model with two are insufficient for two service levels. The genetic algorithm produced qualitatively superior results in optimal values, the accuracy of allocation and timeframe. Jusoh et al (2022) on 'Initial Assessment of Fire Response Time between Different Categories of Fire Stations in Malaysia' that distance traveled demonstrated a directly proportional relationship with response time, and The findings indicate that the development of new fire stations is inevitable in order to reduce the fire incident response time in Malaysia. Developing new fire stations in strategic locations based on the risk profiling schedule and analyzing urban planning, particularly in semi-urban areas, would ensure fast response by firefighters.

iv. Drill / Exercise.

According to the Department of Homeland Security, exercises are the best way to maintain the readiness of teams to respond effectively to an emergency (Department of Homeland Security, 2017). Benefits of drills and exercises to industrial fire brigade emergency responders may include enhanced knowledge and coordination of emergency plans and the ability to test emergency management procedures and protocols with inter-agencies and other response partners. Industrial fire brigade emergency responders may also use exercises to clarify roles and responsibilities and improve individual emergency management performance. In general, exercise requirements usually demonstrate how organizations will meet both routine and disaster-related obligations during a disaster or emergency. They can be used to test these functions during any stage of the disaster management cycle – preparedness, response, recovery, and mitigation of all hazards. Gebbie et al (2006) defined that the exercises may be either discussion or operations-based, including workshops, seminars, and tabletop exercises, while operations-based exercises include drills, functional or Exercises. Klima et al (2012) stated that 'Full Scale Exercise' (FSE) is the most comprehensive way of evaluating multi-agency and multi-jurisdictional readiness; however, they require extensive financial resources, as well as planning, personnel, and subject matter expertise. FSE exercises are intended to evaluate many aspects of emergency operations, including communications, command structure, staffing, logistics, and operations in an interactive manner over days or weeks as they are conducted in real-time.

v. Standard Operating Procedure (SOP)/Guideline to response

According to Gwynne et al, (1999), procedural considerations that may influence turnout time include training levels, prior knowledge of the facility, the efficiency of donning safety equipment, and safety rules. Quińones et al (1995) stated that an individual's experience with any given task positively correlates with performance. Grund C et al (2008) described that experience is often attributed to more senior employees, but it is important to note that a mixed workforce of all experience levels has been shown to garner the best performance for an organization. Continued training will build confidence and the ability for firefighters to respond to an emergency as efficiently as procedural requirements allow.

Summary of Recommendation

It is recommended that

i. The industrial fire brigade to commence a comprehensive review of its compliance with NFPA 1081: Standard for Industrial Fire Brigade Member Qualifications and its significant impact, being fulfilled and implemented.
ii. To assess current industrial fire brigade emergency resources and how significant NFPA 600*:* Standard on Facility Fire Brigades are being complied.
iii. To develop and measure by Modelling & Simulation the top 5 parameters (competency, detection system, location/mapping, drill/exercise, and SOP) emergency response time model and its significant impact on reducing emergency response time for the industrial fire brigade.

Conclusion

It is obvious that the competency, detection system, location/mapping, drill/exercise, and SOP parameters are the most crucial requirement for effective emergency response time. Overall, further research efforts need to be made to investigate the challenges emerging from all parameters, particularly in the context of the industrial fire brigade for oil and gas facility, including efficient emergency management system, link to government fire brigade protocol, and intuitive new fire safety technology. A detailed pilot research analysis has been conducted to highlight the significance of the different perspective of respondents. The main challenges pertain to effectively dealing with data collection and developing efficient systems of model of response time parameters associated with emergency or managing disasters in ways that result in minimum losses to human lives and property. Nevertheless, the literature review provided should help to better understand how pilot test findings can be successfully used for mitigating their effects, controlling, and managing emergencies and improving human capability. Additional efforts are still required to put together all parameters for better use and integration, artificial intelligence techniques and Geographic Informative Systems.

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