fire

MDPI

Article

Initial Assessment of Fire Response Time between Different Categories of Fire Stations in Malaysia

Wan Nursheila Wan Jusoh [1,*], Ahmad Faiz Tharima [2], Wahyunah Ghani [1], Nur Hafizah Mohamad Lukman [2], Sunthaar Visvasathan [2], Mohd Hafizi Shamsudin [1], Nurul Zuhairah Mahmud Zuhudi [1] and Nurhayati Mohd Nur [1]

1 Malaysian Institute of Aviation Technology, Universiti Kuala Lumpur, Jalan Jenderam Hulu, Dengkil 43800, Selangor, Malaysia
2 Planning and Research Division, Fire and Rescue Department of Malaysia, Lengkok Teknologi, Kawasan Perindustrian Enstek, Nilai 71760, Negeri Sembilan, Malaysia
* Correspondence: wannursheila@unikl.edu.my

Abstract: Response time is an important factor in fire operations. A continuous assessment of response time is crucial in order to monitor firefighters' performance level. An initial assessment of fire response time was conducted for fire stations in categories A-D throughout Malaysia from 2018 to 2020. The categories were determined based on risk profiling scores. In this study, the mean response time and distance travelled for the selected fire stations were calculated. To measure the fire station's performance, a 10 min standard response time was used as a benchmark. One-way analysis of variance (ANOVA) was also applied to statistically determine any significant differences between mean response time and mean distance travelled. Among the four categories, category C and D fire stations recorded high values for mean distance travelled and mean response time. Category C fire stations recorded the mean response time, at 15.1 min, and distance travelled, 20.1 km. The areas where category D fire stations are located have low population density, resulting in greater coverage for the stations. Most of the fire stations in this category had approximately 13.8 km travel distance with a mean response time of 17.9 min. Category C and D fire stations require a substantial amount of time to reach incident locations due to the low-quality road network and the local topography. A new profiling method for minimizing fire risk based on constant development in these areas might be necessary for future improvement. Additionally, new category C and D fire stations would meet the demands of expanding communities. It is important to note that establishing a demand zone in Malaysia with specific response time could give a better indication of firefighters' performance in the future.

Keywords: fire; response time; fire station; ANOVA; demand zone

check for updates

Citation: Wan Jusoh, W.N.; Tharima, A.F.; Ghani, W.; Mohamad Lukman, N.H.; Visvasathan, S.; Shamsudin, M.H.; Mahmud Zuhudi, N.Z.; Mohd Nur, N. Initial Assessment of Fire Response Time between Different Categories of Fire Stations in Malaysia. *Fire* **2023**, *6*, 6. https://doi.org/10.3390/fire6010006

Academic Editor: Alistair M. S. Smith

Received: 28 June 2022
Revised: 27 November 2022
Accepted: 9 December 2022
Published: 27 December 2022

1. Introduction

Fire departments are constantly working with numerous measurements to improve their performance and effectiveness. An essential indicator in the management of any emergency call is the response time. Response time is considered to be one of the key factors in emergency response, and should be further examined as firefighters are aiming to reduce deaths and property damage. Response time has been widely investigated by various researchers, such as Carlotti et al. [1], who conducted a statistical analysis of intervention reports of fires. In addition, various factors that influence effective emergency response have been studied; for example, Kerber et al. [2] considered other factors, such as home size, type, geometry, contents, and construction materials, in the analysis. A prompt response by the fire department to the scene is crucial in minimizing the damage a fire can cause to structures and public safety. Suppressing a fire before flashover occurs will reduce the fire's ability to grow and spread to adjacent areas. Large amounts of heat and smoke are generated during flashover, reducing the chance of saving occupants. Flashover time has also received quite a bit of attention in the literature, with studies showing that the time to flashover is influenced by the construction materials, floor plan, volume and layout, and synthetic fuel loads, as reported by Kerber et al. [2].

Several researchers have studied the flashover period. Babrauskas et al. [3] stated that in a room with flammable material, flashover will typically occur within 3 to 6 min. After a flashover, the chance of achieving a successful fire extinguishing operation is extremely low.

As reported by Wrack [4], a fire that has been burning for 9 min can be extinguished by the first team that reaches the location. In contrast, for an outbreak that occurs over 9 min, the full team should be deployed with equipment. It can be concluded that a firefighter response time $\geq$ 10 min can lead to further physical injury, worse property damage, and difficulty controlling the fire.

According to National Fire Protection Association (NFPA) standard 1710 [5] on fuel types, the predicted time to flashover for most flammable materials is 10 min. The total response time is the period from receiving the alarm until the arrival of the first responder team at the scene to initiate action or control the incident. Response times are frequently determined by different measures by firefighters and reported to the public using different approaches.

Claridge and Spearpoint [6] studied the response time of the New Zealand Fire Service. The response time analysis was established based on topographic conditions and divided into urban and rural areas. The response time for permanent fire stations indicated 90% achievement at 7 min 30 s, compared to 90% at 10 min for volunteer-based fire stations. The United Kingdom fire standards are divided into four risk categories, A, B, C, and D, with response times of 5, 8, 10, and 20 min, respectively [7].

Apart from the above studies, Yeomans [8] also conducted response time analyses in various areas in the United States. The author described two zones, with zone A representing more developed districts and zone B including rural areas with smaller populations. The fastest response time was 7 min 30 s for zone A and 10 min 30 s for zone B.

Several studies investigated response time to monitor the service performance and capability of fire organizations. The response requirements vary greatly between countries. The standard response time of the Fire and Rescue Department of Malaysia (FRDM) is 10 min. There have been limited studies on FRDM response times in recent years, which focused only on specific districts or states [9–11]. This study conducted an initial assessment of the response time across different fire station categories and states in Malaysia. In addition, the distribution of fire station categories was identified and the mean response times were compared using analysis of variance.

2. Methodology

2.1. Data Collection

The fire response time data from 2018 to 2020 were obtained from FRDM. The data were based on fire stations in 4 categories in 5 states: Johor, Kedah, Pahang, Selangor, and Sarawak (Figure 1). Each state represents a specific geographical region: East Coast, Northern, Southern, and West Coast Peninsular Malaysia, and East Malaysia.

The initial data comprised fire and rescue incidents, including special tasks assigned, such as supporting other government agencies with natural disaster relief and handling wildlife. For this study, response times in fire incident data recorded from 2018 to 2020 were selected for further analysis. Other response time factors, including number of firefighters, equipment, and station management, were considered as constant variables for this initial assessment. The State Operations Management Centre or fire station control rooms involved in fire incidents log the response time data in the Malaysian Emergency Response Services (MERS) 999 system. The control room duty officer records the interval directly in the MERS 999 system.

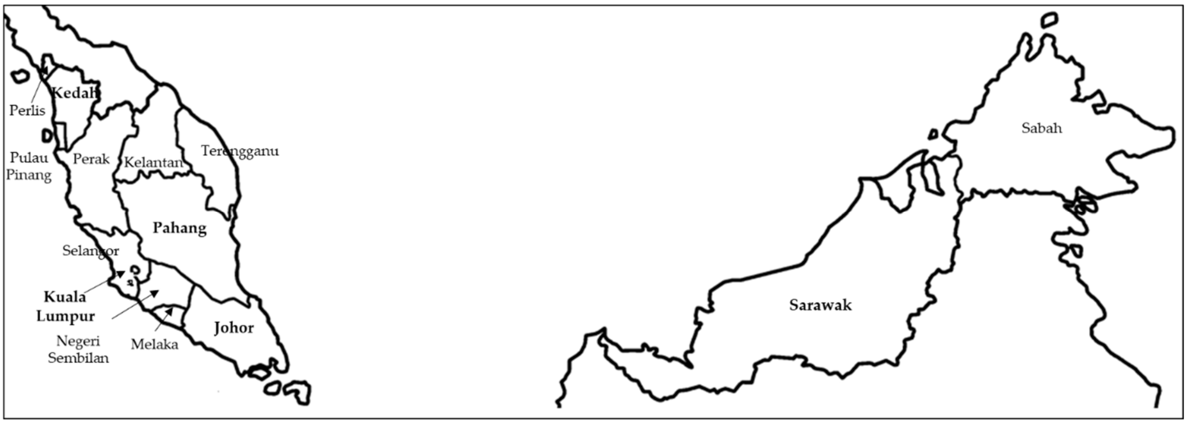

Figure 1. Map of states in Malaysia.

The FDRM emergency response time was calculated as follows:

Response time = time of arrival at the scene–time alarm was acknowledged at fire station control room

2.2. ANOVA

Several organizations publish a considerable amount of statistical data on fires via annual reports on fires and fire departments. Unfortunately, the actual firefighter performance and the relationship between firefighting operations are not included in most statistics [12].

This study used one-way ANOVA to determine statistically significant differences between the mean response time and mean distance travelled. The first stage of ANOVA involved constructing a hypothesis statement set consisting of a null hypothesis (H_0 : all means are equal) and an alternative hypothesis (H_a : at least one mean is not equal).

Two variance estimations were used for calculation in ANOVA. The first estimation referred to inter-sample variance, or mean square between samples (MSB). The second estimation referred to intra-sample variance, or within mean square (WMS). The statistical value for testing a hypothesis using ANOVA is test statistic F, which is calculated as the ratio of the two variances (MSB/MSW). The formula of test statistic F is as follows:

$$\mathrm{F} = \frac{\mathrm{MSB}}{\mathrm{MSW}} = \frac{\left[\left(\frac{T_1^2}{n_1} + \frac{T_2^2}{n_2} + \frac{T_3^2}{n_3} + \cdots\right) - \frac{(\sum x)^2}{n}\right]/k-1}{\left[\sum x^2 - \left(\frac{T_1^2}{n_1} + \frac{T_2^2}{n_2} + \frac{T_3^2}{n_3} + \cdots\right)\right]/n-k} \quad (1)$$

where x is response time, k is number of fire stations, n_i is the response time for each fire station, T_i is the sum of response times in fire stations, and n is the response time for all fire stations.

One-way ANOVA is always right-tailed, and the right tail of the F distribution curve contains a rejection region. In this paper, the rejection region was $\alpha = 0.05$. If the ANOVA p-value fell within the rejection region, the null hypothesis would be rejected. The hypotheses were stated as follows:

$\mathbf{H_0}$: *The mean response time is equal for all fire stations.*

$\mathbf{H_a}$: *At least one mean response times of fire stations are not equal.*

2.3. Post Hoc Test

Post hoc tests, or multiple comparisons, confirmed which groups had different means. Such tests could only be performed if ANOVA demonstrated an overall statistically significant difference in group means. All pairwise differences among group means were the groups of interest; $\mu_i - \mu_j$ for all $i \neq j$. There are diverse post hoc tests, but the most common for comparing all possible group pairings and widely applied for parametric statistical analysis is Tukey's method [13]. It is also known as the honestly significant difference (HSD) test. The main concept of the HSD is the computation of the honestly significant difference between two means using a statistical process. The process will identify the major difference between the means of a set of groups.

The *p*-value identified significant differences in group comparisons, with *p*-values compared to the significance level. A *p*-value less than the significance level indicates that the difference between those group means is statistically significant.

A need for post hoc tests produced the homogeneous subset as output. The homogeneous subset results determined the group means in ascending order. Each subset contained a set of means not significantly different from each other.

3. Results and Discussion

3.1. Data Description

Currently, there are 324 fire stations in Malaysia. These are categorized as A, B, C, D, and E. Nationwide, 52.8% of fire stations (n = 171) fall into category C, indicating moderate fire risk locations; 25.3% (n = 82) are in category B, indicating high-risk locations; and 11.7% (38) are in category A, for very high-risk areas. Category E fire stations were excluded from this study as the category encompasses only 1 fire station.

Risk profiling scores were calculated based on criteria such as population size, industry size, and type of residence. A risk profiling score > 35 points for category A fire station locations refers to urban areas or high-risk industrial properties, while a score of 19–27 points for category C fire station locations refers to smaller cities with large construction areas, such as multi-story residences. The Malaysian demographic is primarily classified under category C.

The current risk profile used by FRDM might be different to risk profiling used in the United States, where only the number of population per mile is considered [14], while British Standard Institution Published Document 7974-5 [15] only takes into account main shopping malls and business center, movie theaters, and other entertainment centers or high-risk industrial properties for category A. Figure 2 illustrates the distribution of fire stations in Malaysia according to category.

The facilities and equipment for each station quantify the degree of potential fire hazard according to the risk profile score. Category A fire stations are well-equipped with fire rescue tenders (FRTs), water tankers (WTs), emergency medical rescue service (EMRS), and special vehicles such as aerial ladder platforms (ALPs). By contrast, fire stations in the other categories receive less equipment and resources. For example, only FRTs and WTs are available to category C stations.

3.2. Fire Incidents of Selected Stations

A total of 20 fire stations were included in this study (listed in Table 1), with 10,233 fire incidents recorded. Some of the recorded data yielded a negative value due to system error and were excluded from the analysis.

Table 1. Fire stations included in this study.

State	Fire Stations			
Johor	Larkin	Kota Tinggi	Pekan Nenas	Yong Peng
Kedah	Alor Setar	Kulim	Pokok Sena	Sungai Petani
Pahang	Bukit Angin	Kuantan	Ringlet	Taman Tas
Sarawak	Kanowit	Limbang	Petra Jaya	Tanjung Manis
Kuala Lumpur	Seputeh	Jalan Hang Tuah	Setapak	Sungai Besi

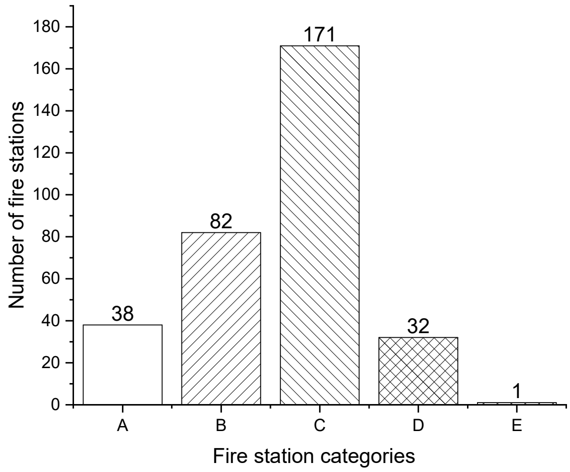

Figure 2. Fire station categories in Malaysia.

Figure 3 illustrates the mean number of fire incidents during 2018–2020 according to category. The number was highest in category A locations, which recorded 50% more fire incidents compared to the other categories. In 2020, there were 15,393 reported fire incidents nationwide from 18 March to 31 August. During the same period in 2018 and 2019, 19,165 and 23,094 fire incidents were reported, respectively [16]. Similar trends were observed for the data from selected fire stations, where reported cases decreased in 2020. This finding could be related to the issuance of the first Movement Control Order (MCO) in the country beginning 18 March 2020 in response to the COVID-19 pandemic. Over the following three years, fire incidents reported for all categories were highest in 2019. Comparing fire stations within similar categories yielded an excellent basis for assessing the response time, as described in the next section.

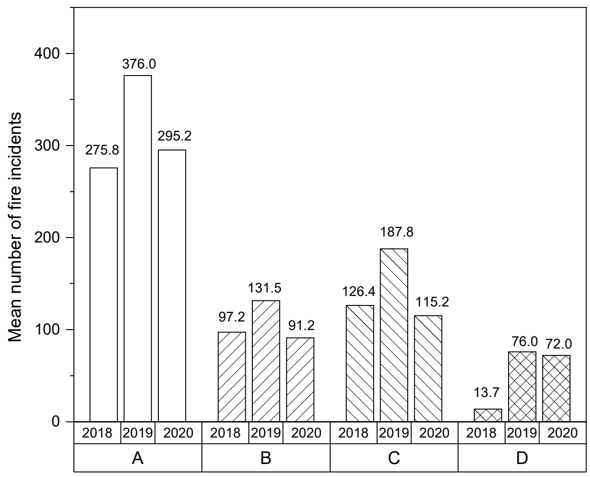

Figure 3. Mean number of fire incidents reported from 2018 to 2020 for selected fire stations in all categories (A, B, C and D).

3.3. Variation in Mean Response Time from 2018 to 2020

This section describes a benchmarking exercise on mean response time from 2018 to 2020 by the selected fire stations. It is not a definitive conclusion of the level of service rendered by FRDM. The data reported are used as a reference for identifying the trends and correlating issues that require further attention. The mean 10 min response time (red line) depicted in the following figures is a national mean response time benchmark.

Figure 4 shows that most of the selected fire stations recorded a mean response time of >10 min in 2018–2020. It is worth noting that the mean response time for category A, C, and D fire stations improved, while category B fire stations maintained the same mean time of 14 min. In 2020, category A and D fire stations met the 10 min standard response time with times of 7.9 and 8.9 min, respectively. The MCO reduced traffic density significantly, which helped in improving the delay for rescue teams arriving at fire incidents as compared to 2019, as supported by Chen et al. [17]. According to studies conducted by Challands [18], quick response time does result in fewer casualties in most incidents. The studies reported that between 4 and 7 min, the response time and the level of casualties are in a positive relationship comprising 63% of occurrences and 69% of casualties.

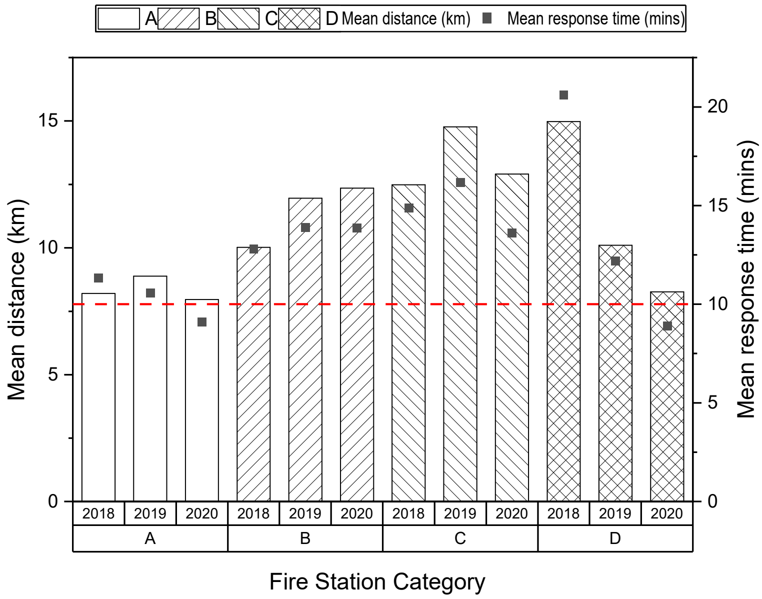

Figure 4. Mean distance travelled and mean response time by fire station category (A, B, C and D). The red dash line is the mean response time benchmark for Malaysia.

The shorter mean distance travelled for category D fire stations could be an important factor in the significant reduction in response time in 2020. Yung [19] and Tómasson et al. [20] reported that one of the main factors influencing response time is the distance travelled, with average speeds of approximately 20 km/h for short distances in city centers reported compared to 70 km/h for longer distances on state highways.

This main factor was validated by Pearson's correlation between response time and distance travelled based on fire station category.

Table 2 shows that there is a strong positive correlation between response time and distance travelled for category B, C, and D fire stations, with values between 0.5 and 1. The highest Pearson correlation value was for category B, with 0.89, followed by categories D and C, with 0.86 and 0.76, respectively. The positive values indicate that response time can increase with distance. Category A fire stations recorded a medium positive correlation (0.39), with p-value < 0.5.

Table 2. Summary of Pearson's correlation analysis.

Station Category	A	B	C	D
Pearson correlation	0.39	0.89	0.76	0.86

Table 3 gives a summary of ANOVA results for mean distance travelled and Tukey's post hoc honestly significant difference (HSD) test for overall mean distance travelled for 2018–2020. The ANOVA result was significant (F (3, 10229) = 250.72 (p-value = 0.00)). As the p-value was <0.05, H_0 can be rejected, meaning that distance travelled was statistically significantly different between station categories. This implies that a different mean distance travelled applies between station category.

Table 3. Summary of ANOVA and Tukey's post hoc HSD test for overall mean distance travelled.

ANOVA				Tukey's Post Hoc HSD Test						
Unit Test	**df**	**F Test**	***p*-Value**	**Multiple Comparison**	***p*-Value**	**Station**	**Homogeneous Subset (km)**			
							1	**2**	**3**	**4**
Station	(3, 10,229)	250.72	0.00 ** (**)	All pairs	<0.05 *	A	8.39			
						D		9.69		
						B			11.48	
						C				13.59

df, degree of freedom. *, ** Significant difference when p-value < 0.05 or <0.01, respectively.

The multiple comparison tests of mean values were significant (p-value < 0.05). The results indicate that the paired categories recorded significantly different mean distances travelled. The homogeneous subset demonstrated that category C fire stations travelled the greatest distance (13.6 km), followed by category B (11.5 km), D (9.7 km), and A (8.4 km). As the ANOVA results were significant, Tukey's post hoc HSD test was performed to compare the means between the two categories.

Table 4 provides a summary of ANOVA results for the mean response time and Tukey's post hoc HSD test. Categories A and D recorded slightly different mean response times while the other paired comparisons showed significantly different values. The homogeneous subset shows that category A fire stations recorded the shortest response time (10.3 min), followed by category D and B fire stations. Category C fire stations recorded the longest mean response time (15.1 min) and did not meet the maximum response time threshold.

Table 4. Summary of ANOVA for mean response time and Tukey's post hoc HSD test.

ANOVA				Tukey's Post Hoc HSD Test						
Unit Test	**df**	**F Test**	***p*-Value**	**Multiple Comparison**	***p*-Value**	**Station**	**Homogenous Subset (Mins)**			
							1	**2**	**3**	**4**
				(A, D)	0.13	A	10.34			
						D		11.43		
Station	(3, 10,229)	121.98	0.00 **			B			13.55	
						C				15.11
				Other pairs	<0.05 *					

df, degree of freedom. *, ** Significant difference when p-value < 0.05 or <0.01, respectively.

Figure 5 shows the mean distance travelled and response times of category A fire stations. The highest values were recorded for the fire station in Kuantan, a city on the Peninsular Malaysia east coast. East coast cities are moderately less dense than cities in western or southern Peninsular Malaysia. In 2019, Kuantan firefighters travelled a mean 11.8 km to fire incident locations. Meanwhile, from 2018 to 2020, the Kuantan fire station recorded a mean distance travelled of 10.7 km with a mean response time of 13.9 min. The Larkin fire station recorded an improved mean response time each year, with a response time of 7.5 min in 2020. The reduced traffic in 2020 may be one of the primary factors in the better response time for category A fire stations.

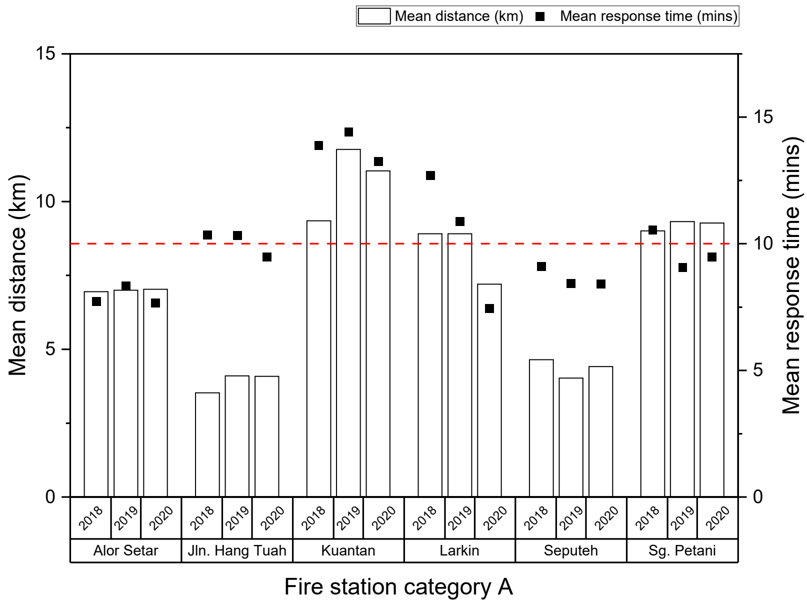

Figure 5. Mean distance and response time for category A fire stations. The red dash line is the mean response time benchmark for Malaysia.

As the ANOVA indicated a significant difference between the stations (F (5, 5676) = 40.22 (*p*-value = 0.00)), Tukey's post hoc HSD test, summarized in Table 5, indicated no difference between the mean response times of the six paired stations. The homogeneous subset for overall mean response time demonstrated that the Alor Setar and Seputeh fire stations met the standard response time; both of them also met the standard response time every year. The Jalan Hang Tuah fire station recorded a low mean distance travelled of 3.9 km. Nevertheless, the high traffic flow and dense population, with businesses located in the area, led to response times in 2018 and 2019 exceeding the standard.

Table 5. Summary of Tukey's post hoc HSD test for mean response time between category A fire stations.

Tukey's Post Hoc HSD Test						
Multiple Comparison	***p*-Value**	**Station**	**Homogeneous Subset (Min)**			
			1	**2**	**3**	**4**
(Alor Setar, Seputeh)	0.92	Alor Setar	7.89			
(Jalan Hang Tuah, Larkin)	0.91	Seputeh	8.63	8.63		
(Jalan Hang Tuah, Seputeh)	0.60	Sungai Petani	9.58	9.58	9.58	
(Jalan Hang Tuah, Sungai Petani)	0.98	Jalan Hang Tuah		10.00	10.00	
(Larkin, Seputeh)	0.06	Larkin			10.60	
(Seputeh, Sungai Petani)	0.78	Kuantan				13.92
Other pairs	<0.05 *					

* Significant difference when *p*-value < 0.05.

The long response time of the Kuantan fire station might be due to its larger coverage area, as the overall mean distance travelled was 10.9 km. The population and industry in this area are distributed quite distant from each other. A New York study reported that travel time increased linearly with the square root of the distance travelled for short distances and proportionally with the distance travelled for long distances [21].

Figure 6 shows that in category B, the Kota Tinggi and Limbang fire stations recorded the highest mean distance travelled and response times from 2018 to 2020, with values of 18.6 km and 17.9 min and 18.5 km and 20.0 min, respectively. These two fire stations also recorded a slight increment in mean response time in 2019 and 2020. The Setapak and Sungai Besi fire stations recorded consistent mean response times. These two stations experience slower traffic movement during peak hours (to and from the office).

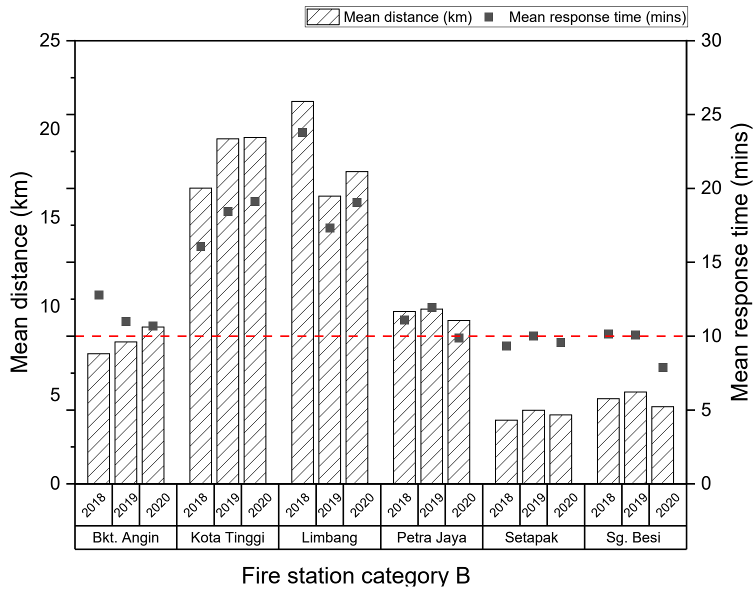

Figure 6. Mean distances travelled and response times recorded by category B fire stations. The red dash line is the mean response time benchmark for Malaysia.

ANOVA revealed that there was a significant difference (F (5, 5676) = 48.15 (*p*-value = 0.00)) between the stations. However, the multiple comparison test in Table 6 yielded no difference between mean response times for the seven pairs of fire stations. The homogeneous subset for overall mean response time divided the stations into two groups. The Sungai Besi, Setapak, Petra Jaya, and Bukit Angin fire stations are in group 1, which means that their response times were within the same range. A major factor in the short mean response time for group 1 is a well-developed road network. Unlike group 1, the group 2 fire stations (Kota Tinggi and Limbang) recorded long mean response times due to geographical limitations. Both of these fire stations may be located in less dense areas, but the road network infrastructure is not as well developed as in group 1. Furthermore, Limbang does not have a road connection with the rest of the Sarawak road network. Aside from the large coverage area of this fire station, this could be a factor for the long distance travelled.

Category C is the largest category of Malaysian fire stations. Figure 7 shows that all fire stations except for Kulim did not meet the standard response times in 2019 and 2020. This category recorded the mean response time, at 15.1 min, and distance travelled, 20.1 km. Kulim is a district in Kedah, a northern Peninsular Malaysian state known for its growing industrial area. Kulim firefighters travelled a mean distance of only 8.6 km for three years compared to the 20.1 km by Kanowit firefighters. Kanowit is a Sarawak district with a less dense population and less development than other areas. This may contribute to the larger coverage of Kanowit fire station compared to other areas. The Taman Tas, Yong Peng, and Pekan Nenas fire stations recorded mean distance travelled of <17 km and decreased mean response time in 2020. The reduced traffic density during the MCO may be the main reason for the shorter response times.

Table 6. Summary of Tukey's post hoc HSD test for mean response times between category B fire stations.

Tukey's Post Hoc HSD Test				
Multiple Comparison	***p*-Value**	**Station**	**Homogeneous Subset (Min)**	
			1	**2**
(Bukit Angin, Petra Jaya)	0.99	Sungai Besi	9.64	
(Bukit Angin, Setapak)	0.37	Setapak	9.69	
(Bukit Angin, Sungai Besi)	0.43	Petra Jaya	11.21	
(Kota Tinggi, Limbang)	0.84	Bukit Angin	11.60	
(Petra Jaya, Setapak)	0.40	Kota Tinggi		18.17
(Petra Jaya, Sungai Besi)	0.49	Limbang		19.41
(Setapak, Sungai Besi)	1.00			
Other pairs	<0.05 *			

* Significant difference when *p*-value < 0.05.

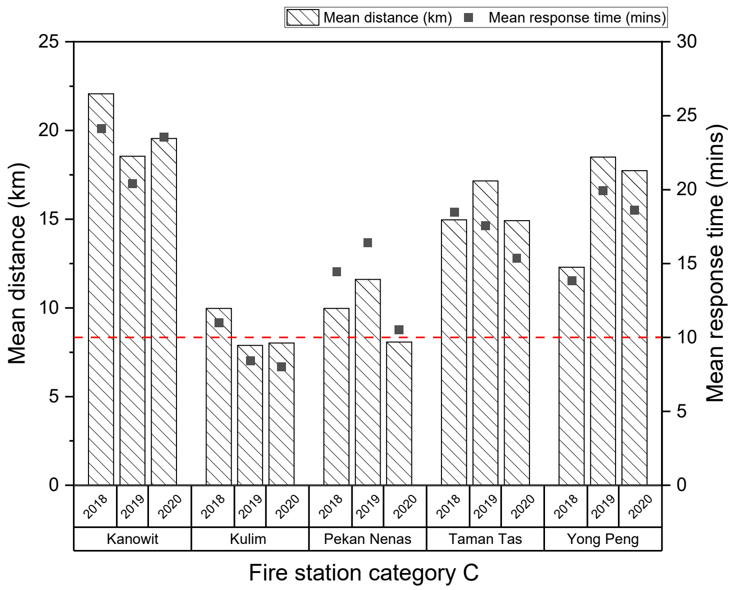

Figure 7. Mean distance travelled and response time recorded by category C fire stations. The red dash line is the mean response time benchmark for Malaysia.

The ANOVA of category C fire stations indicated a significant difference (F (5, 5676) = 68.69 (*p*-value = 0.00)) between the stations. Tukey's post hoc HSD test (Table 7) indicated no difference in mean response time between two paired stations in multiple comparison tests. The homogeneous subset for overall mean response time demonstrated that the Kulim fire station recorded the lowest mean response time (9.2 min), followed by the Pekan Nenas (14.5 min), Taman Tas (17.3 min), Yong Peng (18.2 min), and Kanowit (22.3 min) fire stations.

The areas in which category C fire stations are located are considered developing towns with small-scale industries. These areas were previously rural, with an agricultural economy, and are now shifting to an industrial economy, especially the town of Kulim. The transportation system and residential layout may be affected by the growing demands of the population, which directly influences the response time of rescue teams. The non-uniform speed of vehicles travelling to locations due to poor road design and surface may also explain the longest mean response time for this category.

Table 7. Summary of Tukey's post hoc HSD test for mean response time between category C fire stations.

Tukey's Post Hoc HSD Test						
Multiple Comparison	*p*-Value	Station	Homogeneous Subset (Min)			
			1	2	3	4
(Kanowit, Yong Peng)	0.07	Kulim	9.24			
(Taman Tas, Yong Peng)	0.53	Pekan Nenas		14.53		
		Taman Tas		17.25	17.25	
		Yong Peng			18.19	
		Kanowit				22.34
Other pairs	<0.05 *					

* Significant difference when *p*-value < 0.05.

According to Yang et al. [22], the expansion of the demographic structure has heightened the need for fire services. Previous risk assessment data may no longer be valid. In this situation, a strategic plan is required to establish new fire stations in order to meet the demand in the area.

The areas in which category D fire stations are located are considered semi-rural. The low density of these areas results in fire stations servicing a greater coverage area, as illustrated in Figure 8 for the Ringlet and Tanjung Manis fire stations. Both fire stations recorded a mean distance travelled of approximately 13.8 km with a mean response time of 17.9 min.

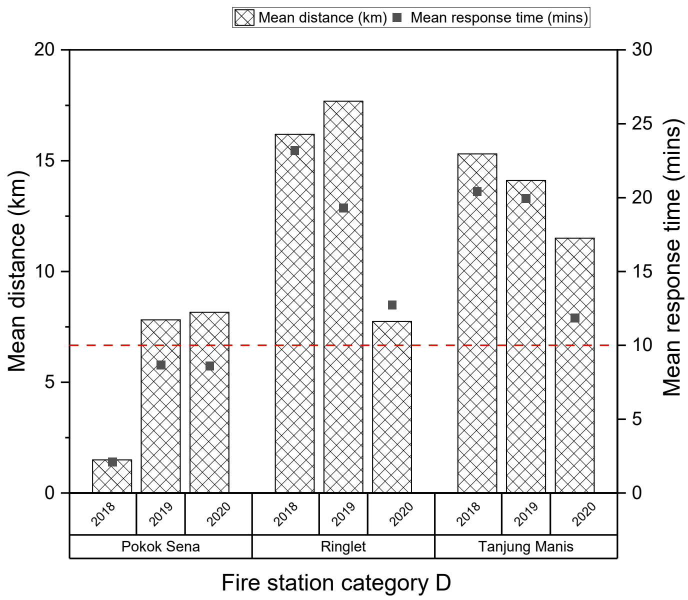

Figure 8. Mean distance travelled and response time recorded by category D fire stations. The red dash line is the mean response time benchmark for Malaysia.

Fire stations in this category do not have the Lite CAD system to capture emergency calls. Instead, emergency calls are transferred by the State Operations Management Center to the fire station control room, creating a delay in response time.

In this category, fire incidents can occur in isolated areas, resulting in longer response times. For example, 30% of the Tanjung Manis area is accessible only by water transport, requiring additional response time. Ringlet is a highland area in Peninsular Malaysia with small perimeter roads and many slow-point lanes. Maneuvering in this landscape is quite challenging for rescue teams, which increases their travel time. Fire engines require unobstructed access roads at least 6 m wide.

The ANOVA of category D indicated a significant difference between the stations (F (5, 5676) = 38.24 (*p*-value = 0.00)). Tukey's post hoc HSD test (Table 8) revealed no difference in mean response times for the Ringlet and Tanjung Manis fire stations. The homogeneous subset for overall mean response time demonstrated that the Pokok Sena fire station recorded the lowest mean response time, and the Tanjung Manis and Ringlet fire stations recorded the highest mean response times. The graph also demonstrates that the Ringlet and Tanjung Manis fire stations recorded improved mean response times every year; nevertheless, they did not meet the standard 10 min response time. In 2020, the Tanjung Manis fire station received a new fire response vehicle as part of departmental improvement [23]. Both the Tanjung Manis and Ringlet fire stations recorded significant decreases in mean response time and mean distance travelled from 2019 to 2020. It is believed that the lower traffic and overall activity during the MCO contributed to smooth traffic flow and shorter distance travelled.

Table 8. Summary of Tukey's post hoc HSD test for mean response time between category D fire stations.

Tukey's Post Hoc HSD Test				
Multiple Comparison	***p*-Value**	**Station**	**Homogeneous Subset (Min)**	
			1	**2**
(Ringlet, Tanjung Manis)	0.99	Pokok Sena	8.62	
		Tanjung Manis		19.31
		Ringlet		19.53
Other pairs	<0.05 *			

* Significant difference when p-value < 0.05

3.4. Future Works

Overall, there is a positive correlation between response time and distance travelled for every category of fire stations. The ANOVA significantly determined the mean response times between the fire station categories, while Tukey's post hoc HSD test validated the results by grouping homogenous response times.

This initial assessment represents 6% of total fire stations in Malaysia and does not define the performance of the total number of fire stations in the country. Therefore, larger sampling sizes will be required for advanced assessment in the future. In the next stage of assessment, the data for mean response time for the FRDM will exclude incidents of fires involving unattended road vehicles or vacant property, or when the response team has become aware of a fire after it has been suppressed (often referred to as a "late call"). This includes a call processing time from MERS 999 to the control room of >200 s, as suggested by the United Kingdom Home Office [24]. Excluding certain parameters could reduce variations in the characteristics of fire incidents to yield a better overview of the mean response time.

Significantly, various countries are divided into zones or demand zones according to the suitability of the area. In order to standardize the usage of demand zones in the context of Malaysia, it is proposed that every fire station in the country be categorized based on the demand zones outlined in international standards such as the NFPA and Malaysian Town and Country Planning Department outline. With this strategy, the response time performance for every fire station will reflect the actual situation in that area.

4. Conclusions

The initial assessment demonstrated that, regardless of category, most of the fire stations recorded a trend of improving response times from 2018 to 2020. In addition, more than half of the category C and D fire stations recorded shorter mean response times in 2019, whereas fire stations in the other categories demonstrated no significant changes. The improved mean response times recorded in 2020 suggests that traffic congestion during fire operations is an important factor in the timing of firefighters arriving at the scene, especially those from category A fire stations.

Distance travelled demonstrated a directly proportional relationship with response time, as illustrated by graphs showing Pearson's correlation of >0.7 for categories B, C, and D. 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 a fast response by firefighters. Furthermore, the risk profiling schedule should be updated to accommodate the rapid urbanization throughout the country. Moreover, it is essential to upgrade fire station facilities to address the increased potential fire risk in communities.

Author Contributions: Writing the original draft, W.N.W.J., A.F.T. and W.G.; formal analysis, W.N.W.J. and W.G.; data extraction, N.H.M.L. and S.V.; writing literature review, M.H.S. and N.Z.M.Z.; data validation, N.M.N. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: Data are from Fire and Rescue Department of Malaysia and not publicly archived.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Carlotti, P.; Parisse, D.; Risler, N. Statistical Analysis of Intervention Reports for Fires Resulting in Casualties Deceased on the Spot in Paris Area. *Fire Saf. J.* **2017**, *92*, 77–79. [CrossRef]
2. Kerber, S. Analysis of Changing Residential Fire Dynamics and Its Implications on Firefighter Operational Timeframes. *Fire Technol.* **2012**, *48*, 865–891. [CrossRef]
3. Babrauskas, V.; Peacock, R.D.; Reneke, P.A. Defining flashover for fire hazard calculations: Part II. *Fire Saf. J.* **2003**, *38*, 613–622. [CrossRef]
4. Wrack, M. It's About Time: Why Emergency Response Times Matter to Firefighters and the Public. The Fire Brigades Union. Available online: https://www.epsu.org/sites/default/files/article/files/6367-Its-about-time-LOW-RES2.pdf (accessed on 27 July 2021).
5. National Fire Protection Association. *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*; National Fire Protection Association: Quincy, MA, USA, 2010.
6. Claridge, E.; Spearpoint, M. New Zealand fire service response times to structure fires. *Procedia Eng.* **2013**, *62*, 1063–1072. [CrossRef]
7. *BS 7974: 2019*; Application of Fire Safety Engineering Principles to the Design of Buildings—Code of Practice. BSI: London, UK, 2019.
8. Yeomans, J. *Fire Department Response Times: What Southeastern Fire Departments Report and Why*; Master of Public Administration dissertation, University of North Carolina at Chapel Hill: Chapel Hill, NC, USA, 2011.
9. Sardi, M.F.; Razak, K.A. Assessment of effectiveness of emergency response time during landslide event in Malaysia. *ASM Sci. J.* **2019**, *12*, 1–19. [CrossRef]
10. Tamat, A.; Pawanchik, S.; Kamil, A.A.; Hilmi, M.F.; Lateh, H.H.; Hasan, Z.; Ferdushi, K.F.; Hossain, K. An analysis of variation of turn out time and response time in Penang state fire and rescue department. *J. Environ. Sci. Technol.* **2014**, *7*, 200–208. [CrossRef]
11. Subramaniam, C.; Ali, H.; Mohd Shamsudin, F. Initial emergency response performance of fire fighters in Malaysia. *Int. J. Public Sect. Manag.* **2012**, *25*, 64–73. [CrossRef]
12. Särdqvist, S.; Holmstedt, G. Correlation between firefighting operation and fire area: Analysis of statistics. *Fire Technol.* **2000**, *36*, 109–130. [CrossRef]
13. Midway, S.; Robertson, M.; Flinn, S.; Kaller, M. Comparing Multiple Comparisons: Practical Guidance for Choosing the Best Multiple Comparisons Test. *PeerJ* **2020**, *8*, e10387. [CrossRef] [PubMed]
14. National Fire Protection Association. *NFPA 1720, Standard for the Organization and Deployment of Fire Suppression Operations, Emergency Medical Operations, and Special Operations to the Public by Volunteer Fire Departments 2020 Edition*; National Fire Protection Association: Quincy, MA, USA, 2020.
15. *BSI PD 7974-5: 2014*; Application of Fire Safety Engineering Principles to the Design of Buildings. Fire and Rescue Service Intervention (Sub-System 5). BSI: London, UK, 2014.
16. Challands, N. The Relationships between Fire Service Response Time and Fire Outcomes. *Fire Technol.* **2010**, *46*, 665–676. [CrossRef]
17. Mohammad, N.H. Firefighters Dealt with More Fires in First MCO. Star. Available online: https://www.thestar.com.my/news/nation/2020/12/12/firefighters-deal-with-more-fires-in-first-mco (accessed on 20 May 2021).

18. Chen, Y.; Qin, R.; Zhang, G.; Albanwan, H. Spatial temporal analysis of traffic patterns during the COVID-19 epidemic by vehicle detection using planet remote-sensing satellite images. *Remote Sens.* **2021**, *13*, 208. [CrossRef]
19. Yung, D. *Principles of Fire Risk Assessment in Buildings*, 1st ed.; Wiley: Hoboken, NJ, USA, 2008; ISBN 9780470854099.
20. Tomasson, B.; Bengtsson, J.; Thorsteinsson, D.; Karlsson, B. A Probabilistic Risk Analysis Methodology for High-Rise Buildings Taking into Account Fire Department Intervention Time. *Fire Saf. Sci.* **2008**, *9*, 957–968. [CrossRef]
21. Kolesar, P.; Walker, W. *Measuring the Travel Characteristics of New York City's Fire Companies*; RAND Corporation: Santa Monica, CA, USA, 1974.
22. Home Office (UK). *Response Times to Fires Attended by Fire and Rescue Services*; Home Office: London, UK, 2020; Volume 20, pp. 1–16.
23. Yang, B.; Viswanathan, K.; Lertworawanich, P.; Kumar, S. Fire Station Districting Using Simulation: Case Study in Centre Region, Pennsylvania. *J. Urban Plan. Dev.* **2004**, *130*, 117–124. [CrossRef]
24. Nancy, N. Bomba Receives 723 PPE, New Vehicles for Operations. *DayakDaily*, 26 August 2020.