

Analysis and Simulation of Evacuation Routes During Disaster Situations: A Case Study in Kuala Lumpur City (KLC)

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ABSTRACT

Kuala Lumpur City (KLC) is susceptible to disasters because of its large population, crucial infrastructure, and vital economy. In this study, we used the disaster risk maps generated for flash floods and landslide hazards in KLC to identify key areas for humanitarian assistance and disaster relief (HADR) activities. We employed analysis and simulations to determine the most effective evacuation routes from key areas to crucial HADR centres, including medical facilities, police stations, fire stations, and temporary evacuation centres, during a disaster. We conducted the investigation by considering factors like evacuation time, route accessibility, and overall efficiency. We proposed multiple routes during the disaster scenario, including the use of alternative roads with reduced capacity if the major roads became inaccessible. This case study highlights the significance of ongoing evaluation and improvement of evacuation preparations. The measures, including the use of cutting-edge traffic management systems, frequent practice sessions and instruction for emergency responders, and heightened public awareness and preparedness initiatives, could potentially improve evacuation time. By implementing these strategies, KLC may enhance its ability to withstand and respond to disaster scenarios, thereby safeguarding lives and mitigating the potential consequences of disasters. The results of this study could provide useful insights for Kuala Lumpur City Hall to plan evacuation routes during a disaster.

Keywords: Urban disaster; landslides; flash flood; riskmap; evacuation routes

INTRODUCTION

Kuala Lumpur, the capital city of Malaysia, covers an area of around 243 square kilometres, accounting for around 0.07% of Malaysia's total land area. Nevertheless, it has a census population of almost 2 million, accounting for roughly 6% of Malaysia's total population as of January 1, 2023 (OpenDOSM 2024). Kuala Lumpur has a moderate population density of 8,225 individuals per square

kilometre. Kuala Lumpur boasts numerous skyscrapers and serves as a significant economic centre. The notable structures in Kuala Lumpur include the Kuala Lumpur Tower, which is the seventh tallest telecommunication tower globally. The Petronas Twin Towers consist of two 88-story twin towers and rank as the world's tallest twin towers. Merdeka 118 is a mega-tall skyscraper with 118 stories, which will be the second-tallest building and structure in the world upon completion. Kuala Lumpur Sentral serves as a significant transportation hub, with

various intracity and intercity rail. Thus, Kuala Lumpur is very vulnerable to disasters because of its large population, critical infrastructure, and essential economy.

In an emergency situation, it is crucial to provide humanitarian assistance and disaster relief (HADR). During HADR activities, it is crucial to ensure that assistance is promptly delivered to the community. This study involves conducting a simulation of a disaster situation at Petronas Twin Towers, a renowned skyscraper in Kuala Lumpur. We selected the Petronas Twin Towers as the case study area due to their impressive height of 88 stories and towering 451.9 metres. The Petronas Twin Towers comprise parking facilities, a fitness centre, an art gallery, a philharmonic centre, the Petronas Petroleum Resource Centre, the Petrosains Discovery Centre, office zones, a conference centre, a sky bridge, and an observatory deck. On the other hand, Suria KLCC, a high-end shopping mall situated at the base of the Petronas Twin Towers, is a well-liked destination for tourists. In the event of a disaster, it will have a significant effect on the community residing in the Petronas Twin Towers and Suria KLCC. Therefore, the case study has chosen the Petronas Twin Towers as the subject.

In the past, multiple incidents and accidents have occurred at the Petronas Twin Towers, resulting in tremors and the need for evacuations (Yoong 2001; NBC News 2005; The Star 2008; Malay Mail 2015; Chin 2021; Hakim 2022; Leong 2022; Zikri 2024). These incidents and accidents include fires in 2005, 2022, and 2024; a flash flood on March 7, 2022; bomb threats in 2001, 2008, and 2015; and a recent light rail transit accident near the station located at Petronas Twin Towers in 2021. The fires caused disruptions and evacuations, while the flash flood resulted in water filling the office tower buildings. The bomb threats created chaos and necessitated evacuations. The light rail transit accident caused serious and minor injuries to 47 and 166 passengers, respectively. The frequent occurrence of incidents or accidents at the Petronas Twin Towers requires attention; therefore, in this case study, it is imperative to provide evacuation routes for the community to evacuate the area promptly to ensure the well-being and protection of the local populace.

Therefore, the objectives of this case study are to analyse and simulate the evacuation routes from the Petronas Twin Towers to important HADR centres. For example, in this case study, we aim to move the community from Petronas Twin Towers to the staging area located at the football field of Jalan Padang Tembak under the Ministry of Defence Malaysia (MINDEF). This area boasts an impressive 13 acres of open space, complete with parking and direct access to the main road. This is one of the staging areas proposed for disaster response in Kuala Lumpur City (KLC). Conversely, we simulated the

transportation of first aid response from Kuala Lumpur Hospital to Petronas Twin Towers, and from Petronas Twin Towers back to Kuala Lumpur Hospital. We conducted route simulations from Dang Wangi Police Headquarters and Jalan Tun Razak Fire Department to ensure the police and fire departments could reach the Petronas Twin Towers in the shortest time possible during the disaster situation.

We arranged the remaining papers in the following chronological order: We discuss the importance of simulating evacuation routes in the next section, followed by the study's design. The remaining sections provide the simulation results and discussion. Finally, the last section concludes the study.

THE IMPORTANCE OF SIMULATING EVACUATION ROUTES

The analysis and simulation of evacuation routes are crucial for effective emergency preparedness and response, especially during a disaster situation. It is vital to simulate the evacuation routes to identify potential bottlenecks and congestion points. This process planner will identify areas along the evacuation routes that are prone to traffic congestion and delays, thus enabling planners to improve the routes and implement effective traffic management strategies (Zyryanov and Feofilova 2017; Chu et al. 2019) during the evacuation process. As KLC is a highly congested area, simulating evacuation routes would help the respective authorities involved in HADR operations have proper planning and alternatives during a disaster situation.

The simulation of the evacuation route could also help to minimise evacuation time. Through simulation, we can evaluate various evacuation plans and establish strategies to identify the most efficient evacuation routes and procedures, thereby reducing the risk of injuries and death (Campos et al. 2012; Zyryanov and Feofilova 2017). Furthermore, simulation allows for an assessment of the feasibility of evacuation plans. Planners can evaluate evacuation plans under various scenarios, including damaged road networks from disaster situations like floods or fluctuating traffic conditions due to road disruption, using simulation to confirm their feasibility and successful execution (Chu et al. 2019; Islam et al. 2020). Flash floods are a frequent natural disaster in Kuala Lumpur (Bhuiyan et al. 2018; Bhuiyan et al. 2019; Bhuiyan et al. 2022; Mohd Rofi et al. 2022; Mohtar et al. 2020). During flash floods, some of the KLC routes are inaccessible due to the high-water level, so planning evacuation routes using these high-vulnerability routes requires special consideration.

Simulation also plays a crucial role in facilitating the

coordination of emergency response efforts by aiding different emergency services and agencies participating in an evacuation. It enhances the overall response and minimises confusion among the parties concerned (Chu et al. 2019; Yazdani et al. 2022). Simulation is crucial for training and preparedness. The simulation exercises will enable emergency professionals and the general public to practice evacuation protocols, enhancing their awareness and preparedness for actual disaster scenarios (Sreejith and Sinimole, 2022; Yazdani et al. 2022). The lack of readiness among Malaysian citizens during crisis scenarios has been well documented (Magiswary et al. 2010; Ambitapathy et al. 2024). Therefore, this case study has the potential to enhance community awareness and preparedness.

In summary, simulation of evacuation route is a crucial for developing effective emergency plans, optimising evacuation strategies, and enhancing preparedness to save lives in the event of a disaster (Campos et al. 2012;

Zyryanov and Feofilova, 2017; Chu et al. 2019; Islam et al. 2020; Sreejith and Sinimole 2022; Yazdani et al. 2022).

THE STUDY DESIGN

The focus of this case study is on four crucial HADR centres from Petronas Twin Towers (PTT). Figure 1 depicts the study location, which is the PTT. It also shows the HADR centres: Kuala Lumpur Hospital (KLH), situated in the north-west region of the PTT; the Dang Wangi District Police Head Quarter (DWDPHQ), located in the west region; the Jalan Tun Razak Fire and Rescue Station (JTRFRS), situated in the north-east region; and the staging area at the Ministry of Defence (MINDEF) football field (MINDEFFF), also located in the north-east region of the PTT. Table 1 presents the coordinates of these localities.

TABLE 1. PTT to HADR centre

Location	Coordinates
PTT	3.157831336958681, 101.71155621305981
DWDPHQ	3.1566008480050467, 101.69804975211609
JTRFRS)	3.163756459006646, 101.71744228095139
MINDEFFF	3.174283589020555, 101.72567784701626
KLH	3.17172892005598, 101.7025420944454

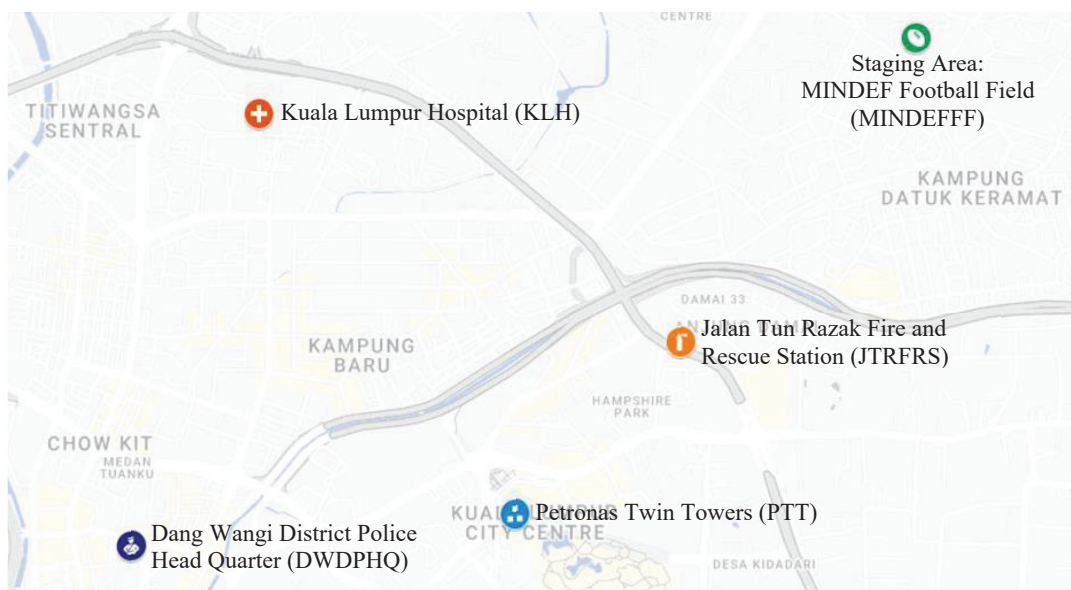


FIGURE 1. Study location

We suggested at least two routes from each HADR centre to PTT. Tables 2–6 and Figures 2-6 display a summary of these routes. We measured the distance of each route and used Google Maps to estimate the anticipated travel time of a specific route from origin to destination,

taking into consideration traffic conditions on a typical weekday at 15-minute intervals from 0000 to 1145. The anticipated travel time considers the synchronization of traffic signals along the routes and traffic conditions during both peak and off-peak periods.

TABLE 2. Propose evacuation routes from KLH to PTT

No.	KLH to PTT	Route 1	Route 2	Route 3
		via Jalan Raja Abdullah	via Jalan Sultan Ismail	via Jalan Tun Razak
	Distance	2.9	3.8	4.2
	Minimum Time (minutes)	7	9	9
	Maximum Time (minutes)	22	30	30
1	Lorong Iktar	√	√	√
2	Jalan Utama Hospital	√	√	√
3	Lorong Angkut	√	√	√
4	Jalan Masjid	√	√	√
5	Jalan Dr. Latif	√	√	
6	Lorong Raja Muda Abdul Aziz			√
7	Jalan Raja Muda Abdul Aziz*		√	√
8	Jalan Tuanku Abdul Rahman**		√	
9	Jalan Raja Abdullah	√		
10	Jalan Sultan Ismail	√	√	
11	Jalan Tun Razak			√
12	Jalan Ampang	√	√	√
13	Jalan P. Ramlee	√	√	√
14	Persiaran Petronas	√	√	√

TABLE 3. Propose evacuation routes from PTT to KLH

No.	PTT to KLH	Route 1	Route 2	Route 3
		via Jalan Raja Abdullah	via Jalan Sultan Ismail	via Jalan Tun Razak
	Distance	5.3	4.5	7.2
	Minimum Time (minutes)	9	12	14
	Maximum Time (minutes)	35	35	45
1	Persiaran Petronas	√	√	
2	Jalan Pinang	√	√	
3	Jalan Kia Peng	√		
4	Jalan Stonor	√		
5	Persiaran Stonor	√		
6	Jalan Perak		√	√
7	Jalan P. Ramlee		√	√
8	Jalan Sultan Ismail		√	√
9	Jalan Kuching***			√
10	Lebuhraya Sultan Iskandar			√
11	Jalan Tun Razak	√		√
12	Jalan Pahang***			√
13	Jalan Utama Hospital			√
14	Lorong Angkut			√

continue ...

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15	Lorong Raja Muda Abdul Aziz	√		
16	Jalan Ampang		√	
17	Persiaran Capsquare		√	
18	Jalan Raja Abdullah		√	
19	Jalan Dr. Latif		√	
20	Jalan Masjid	√	√	√
21	Lorong Iktar	√	√	√

TABLE 4. Propose evacuation routes from DWDPHQ to PTT

No.	DWDPHQ to PTT	Route 1	Route 2
		via Jalan Ampang	via Jalan Sultan Ismail
	Distance	1.7	2
	Minimum Time (minutes)	4	5
	Maximum Time (minutes)	18	20
1	Jalan Dang Wangi	√	√
2	Jalan Ampang	√	√
3	Jalan Sultan Ismail		√
4	Jalan P. Ramlee	√	√
5	Jalan Pinang		√
6	Persiaran Petronas	√	√

TABLE 5. Propose evacuation routes from JTRFRS to PTT

No.	JTRFRS to PTT	Route 1	Route 2
		via Jalan Ampang	via Jalan Yap Kwan Seng
	Distance	1.9	2
	Minimum Time (minutes)	3	4
	Maximum Time (minutes)	16	16
1	Jalan Tun Razak	√	√
2	Jalan Ampang	√	
3	Jalan Yap Kwan Seng		√
4	Jalan P. Ramlee	√	√
5	Persiaran Petronas	√	√

TABLE 6. Propose evacuation routes from PTT to MINDEFFF

No.	PTT to MINDEFFF	Route 1	Route 2	Route 3
		via Jalan Tun Razak	via Jalan Ampang	via AKLEH
	Distance	5.4	6.7	8.2
	Minimum Time (minutes)	9	12	12
	Maximum Time (minutes)	30	40	40
1	Persiaran Petronas	√	√	√
2	Jalan Pinang	√	√	√
3	Jalan Kia Peng	√	√	√
4	Jalan Stonor	√	√	√
5	Persiaran Stonor	√	√	√
6	Jalan Tun Razak***	√	√	√

continue ...

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7	AKLEH*			√
8	Jalan Ampang***		√	
9	Jalan Jelatek		√	
10	Jalan Datuk Keramat		√	√
11	Jalan Keramat		√	√
12	Jalan Bukit Keramat		√	√
13	Jalan Sultan Yahya Petra	√		
14	Jalan Selangor	√		
15	Jalan Padang Tembak	√	√	√

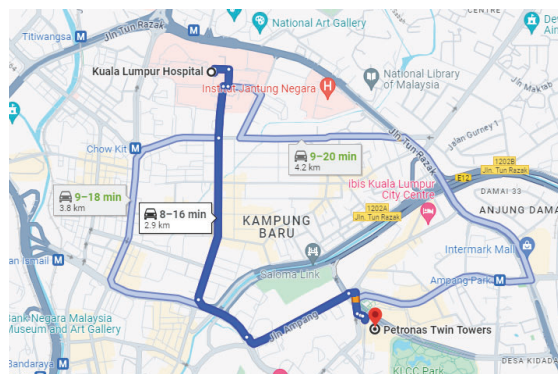


FIGURE 2. Propose evacuation routes from KLH to PTT

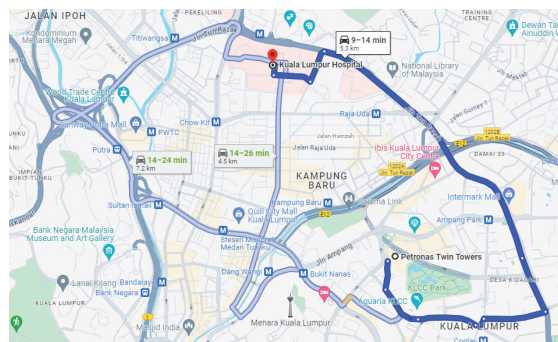


FIGURE 3. Propose evacuation routes from PTT to KLH



FIGURE 4. Propose evacuation routes from DWDPHQ to PTT



FIGURE 5. Propose evacuation routes from JTRFRS to PTT

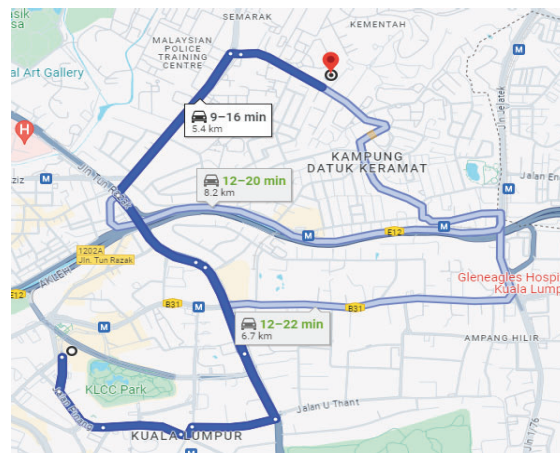


FIGURE 6. Propose evacuation routes from PTT to MINDEFF

SIMULATION

Before running the simulation, we calculated each route's average travel speed using the minimum and maximum trip times, as shown in Tables 7 and 8. These trip times were estimated by Google Maps based on real-time traffic situations in KLC, including traffic signal timing. All routes

generally had an average travel speed below 30 km/h, with the exception of several that exceeded this limit, as shown in Tables 7 and 8. Improving traffic signal systems or reducing congestion could enhance the efficiency of HADR operations by increasing the average travel speed, as indicated in previous research (Zyryanov and Feofilova 2017; Chu et al. 2019).

TABLE 7. Travel times and average speed variation for various routes from various HADR centre to PTT

Item	From KLH to PTT			From DWDPHQ to PTT		From JTRFRS to PTT	
	Route 1	Route 2	Route 3	Route 1	Route 2	Route 1	Route 2
Distance	2.9	3.8	4.2	1.7	2	1.9	2
Time (minutes)	7 - 22	9 - 30	9 - 30	4 - 18	5 - 20	3 - 16	4 - 16
ATS (km/h)	7.9 - 24.9	7.6 - 25.3	8.4 - 28.0	5.7 - 25.5	6.0 - 24.0	7.1-38	7.5-30.0

TABLE 8. Travel times and average speed variation for various routes from PTT to HADR centre

Items	From PTT to KLH			From PTT to MINDEFF		
	Route 1	Route 2	Route 3	Route 1	Route 2	Route 3
Distance	5.3	4.5	7.2	5.4	6.7	8.2
Time (minutes)	9 - 35	12 - 35	14 - 45	9 - 30	12 - 40	12 - 40
ATS	9.1 - 35.3	7.7 - 22.5	9.6 - 30.9	10.8 - 36.0	10.1 - 33.5	12.3 - 41.0

We performed a simulation for each route from the origin to the destination using manual calculations in Microsoft Excel worksheets. In the simulation, we generated random variables that followed a Poisson distribution, accounting for the minimum and maximum travel time required to reach the destination from the origin. Additionally, we took into account the hierarchical structure of the routes, which reflected each route's level

of mobility and accessibility, capacity, and vulnerability (roads without * indicate very low vulnerability, roads with * indicate low vulnerability, and roads with *** indicate high vulnerability). We generated a total of 50 sets of simulation data for the analysis. We also calculated the average travel speed from the travel time generated for analysis purposes. Tables 8–10 present a summary of the descriptive data for the simulation.

TABLE 8. Travelling time and average travel speed from KLH to PTT and vice versa

Data	KLH to PTT						PTT to KLH					
	Time			Average Travel Speed			Time			Average Travel Speed		
	Route 1	Route 2	Route 3	Route 1	Route 2	Route 3	Route 1	Route 2	Route 3	Route 1	Route 2	Route 3
Mean	14.52	18.86	17.92	13.60	13.23	15.84	21.26	24.50	28.24	17.24	12.14	17.02
SD	4.73	5.49	6.08	5.36	4.18	5.61	7.70	6.98	8.90	6.84	4.15	5.80
Kurtosis	-1.11	-1.05	-1.09	0.07	0.18	-0.57	-1.22	-1.20	-1.22	-0.22	-0.08	-0.62
Skewness	-0.07	0.17	0.31	1.07	0.82	0.61	0.21	-0.26	0.13	0.79	1.00	0.66
Min.	7	9	9	7.91	7.86	8.40	9	12	14	9.09	7.71	9.60
Max.	22	29	30	24.86	25.33	28	35	35	45	35.33	22.50	30.86
Sum	726	943	896	679.85	661.29	791.83	1063	1225	1412	862.09	606.91	850.79
n	50	50	50	50	50	50	50	50	50	50	50	50

TABLE 9. Travelling time and average travel speed from DWDPHQ and JTRFRS to PTT

Data	DWDPHQ TO PTT				JTRFRS TO PTT			
	Time		Average Travel Speed		Time		Average Travel Speed	
	Route 1	Route 2	Route 1	Route 2	Route 1	Route 2	Route 1	Route 2
Mean	11.16	14.30	11.44	9.74	8.88	9.38	17.43	15.60
SD	4.71	4.51	5.91	4.61	4.28	3.98	10.81	7.31
Kurtosis	-1.45	-0.82	-0.50	1.60	-1.16	-1.16	-0.43	-0.52
Skewness	-0.07	-0.70	0.89	1.60	0.13	0.30	1.04	0.80
Min.	4	5	5.67	6.00	3	4	7.13	7.50
Max.	18	20	25.50	24.00	16	16	38	30
Sum	558	715	571.838	487.03	444	469	871.74	780.20
n	50	50	50	50	50	50	50	50

TABLE 10. Travelling time and average travel speed from PTT to MINDEFFF

Data	PTT to MINDEFFF					
	Time			Average Travel Speed		
	Route 1	Route 2	Route 3	Route 1	Route 2	Route 3
Mean	18.6	26.62	26.96	19.45	17.37	20.44
SD	6.060	9.11	8.30	6.66	7.10	7.63
Kurtosis	-1.15	-1.32	-1.07	-0.57	-0.30	0.20
Skewness	0.26	-0.10	-0.14	0.61	0.93	1.08
Min.	9	12	12	10.80	10.05	12.30
Max.	30	40	40	36.00	33.50	41
Sum	930	1331	1348	972.48	868.41	1021.85
n	50	50	50	50	50	50

SIMULATION FROM KLH TO PTT AND VICE VERSA

To determine whether there is a statistically significant difference in the average travel speed and time of arrival from KLH to PTT across the three proposed routes, we performed a one-way analysis of variance (ANOVA) test with equal variances using SPSS. For ANOVA equal variances, a general rule of thumb is to compare the smallest and largest sample standard deviations. Should the ratio between these two sample standard deviations be less than 2, it could indicate that the assumption remains intact (Tabachnick and Fidell 2013).

We used the Bonferroni method for the post-hoc comparisons, maintaining a significance level of 0.05. The results indicated that travel time had a significant impact on the chosen routes. $F(2, 147) = 8.74$; $p = 0.00$. The post-hoc comparison using the Bonferroni method revealed that the travel time on route 1 from KLH to PTT is significantly different from route 2 and route 3. Similarly, the results demonstrate a significant difference in average travel speed on the selected routes from KLH to PTT: $F(2, 147) = 3.86$; $p = 0.23$. The post-hoc comparison using the Bonferroni method indicated that the average travel speed on route 2 is significantly different from route 3.

On the other hand, the simulation conducted from PTT to KLH revealed a notable impact on travel time on the routes selected, as evidenced by the statistical analysis: $F(2, 147) = 9.78$; $p = 0.00$. The post-hoc analysis, employing the Bonferroni method, revealed a substantial disparity in travel time between route 1 and route 3. Furthermore, the findings indicate that the average travel speed has a notable impact on the selected routes, as evidenced by the statistical analysis: $F(2, 147) = 12.782$; $p = 0.00$. The post-hoc comparison, employing the Bonferroni method, revealed a substantial difference in the average travel speed between route 2 and routes 1 and 3.

SIMULATION FROM DWDPHQ AND JTRFRS TO PTT

A student's t-test for two samples assuming equal variances ($p < 0.05$) was conducted to verify whether there was a significant difference in route choice from DWDPHQ or JTRFRS to PTT. Generally, the time required to reach PTT from DWDPHQ using route 1 ($M = 11.16$, $SD = 22.13$) is significantly different from route 2 ($M = 14.3$, $SD = 20.38$), $t(98) = -3.41$, $p = 0.00$. However, the average travel speed required to reach PTT from DWDPHQ using route 1 ($M = 11.44$, $SD = 34.93$) is not significantly different from route 2 ($M = 9.74$, $SD = 21.23$), $t(98) = 1.60$, $p = 0.11$.

A similar test was carried out to ascertain if there were any major differences in the time and average travel speed between LTRFRS to PTT. There was no significant difference in the outcomes of both tests. The t-test results, $t(98) = -0.60$, $p = 0.55$, indicate that there is no significant difference in the travel time between route 1 ($M = 8.88$, $SD = 18.31$) and route 2 ($M = 9.38$, $SD = 15.88$) from JTRFRS to PTT. The average travel speed from JTRFRS to PTT is the same for routes 1 ($M = 17.43$, $SD = 116.87$) and 2 ($M = 15.60$, $SD = 53.42$), $t(98) = 0.99$, $p = 0.32$.

SIMULATION FROM PTT TO MINDEF

We conducted one-way ANOVA equal variance tests to determine the travel time and average travel speed from Petronas Twin Towers to the emergency staging centre at MINDEF Football Field. The analysis showed that travel time had a notable impact on the routes selected. The statistical analysis revealed a significant effect, with $F(2, 147) = 17.79$, $p = 0.00$. The post-hoc analysis, employing the Bonferroni method, revealed a substantial difference in travel time between route 1 and routes 2 and 3. Nevertheless, the findings indicate that the average travel speed did not have a noteworthy impact on the routes selected ($F(2, 147) = 2.40$, $p = 0.94$). The post-hoc analysis, employing the Bonferroni method, revealed that there is no statistically significant difference in the average travel speed across all routes.

DISCUSSIONS AND CONCLUSIONS

It is crucial to carry out HADR operations in the shortest feasible time to ensure prompt delivery to affected victims. The analysis and simulation findings recommend choosing Route 1 (via Jalan Raja Abdullah), a 2.9 km long route for sending emergency first aid from KLH to PTT. Alternatively, we recommend choosing route 1 (via Jalan Raja Abdullah), which spans 5.3 km and transports the victims to KLH for additional medical care upon arrival at PTT. The ANOVA results suggest that route 2 (via Jalan Sultan Ismail) could be considered as an alternative route. Despite being shorter at 4.5 km, route 2 generally takes slightly longer to travel compared to route 1 due to the hierarchy of routes. However, there is no significant difference in travel time between these two routes from PTT to KLH.

To receive police assistance, it is recommended that the police force from the DWDPHQ travel by Route 1 (via Jalan Ampang), which is a shorter route of 1.7 km. In the situation where a fire and rescue team are necessary, they could travel from JTRFRS to PTT using either of the routes

proposed in this study, as the statistical analysis revealed no significant difference in travel time for both routes. Thus, either of these routes might be selected in case of an emergency.

Transporting victims from the disaster site (PTT) to the designated staging area at MINDEF could potentially utilise any of the suggested routes, specifically routes 1 to 3, which have respective lengths of 5.4 km, 6.7 km, and 8.2 km. Nevertheless, the duration of travel on these routes does not vary significantly. Therefore, we can choose any suggested routes, as the urgency of transporting the affected community to the staging area is not as critical as the urgency of transporting the affected community to the hospital for additional medical care.

It is advisable for emergency responders, especially those engaged in HADR operations, to consistently be prepared, practice, and acquaint themselves with the routes from HADR centres to PTT. This will ensure a prompt emergency response and efficient HADR operations. Prior research (Chu et al. 2019; Sreejith and Sinimole, 2022; Yazdani et al. 2022) highlights the importance of emergency professionals and the general public being constantly vigilant and ready for real disaster scenarios. Therefore, conducting simulations of evacuation routes and implementing effective traffic management strategies during such situations could enhance the effectiveness of humanitarian assistance and disaster response (HADR) operations.

In conclusion, this study has considered a case study to analyse and simulate the evacuation routes from HADR centres, specifically the Kuala Lumpur Hospital, Dang Wangi District Police Head Quarter, Jalan Tun Razak Fire and Rescue Station, and staging area MINDEF football field, to Petronas Twin Towers or vice versa in the event of a disaster. The case study offers valuable insights for stakeholders participating in HADR operations to enhance the efficiency of disaster response and recovery efforts. We recommend implementing appropriate traffic management during emergencies, such as controlling traffic lights and prohibiting other traffic, to ensure the smooth execution of HADR activities.

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DECLARATION OF COMPETING INTEREST

None.

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