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# Emergency Management in Building Based On 3D BIM and GIS Technology

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## ABSTRACT

*An emergency route is a route designed for human use to save themselves from dangerous situations. However, if it is considered trivial, this has unknowingly led to an increase in accidents. The provision of emergency routes on a community scale in indoor areas in terms of time is rarely discussed in emergency evacuation studies. This study aims to investigate the emergency route in the building due to the environmental factors of the closed area and the arrangement of office equipment. The method of this study is divided into two sub-sections, namely data preparation and data analysis process. Demographic data and physical interactions were used as the selection of walking speed criteria while the use of geometric data to see the actual plan route position of the building. 3D building models are built through Revit software and then converted to industry foundation classes format (.IFC) and then to multipatch shapefile (.shp) to be integrated into ArcGIS software. This is intended for the use of the data analysis process that is to build a geometric network model (GNM). GNM is designed to determine the safest and shortest routes by taking into account a variety of obstacles based on the scenario conditions. The findings shows that the evacuation time is influenced by the speed and distance of the route. 80% of the safest route selection takes a long time compared to the shortest route, while 20% is the same distance and time for the shortest and safest route because route selection is the same. The findings able to be used as a reference and guideline to determine the selection of emergency routes, especially in complex buildings.*

*Keywords: Emergency Route; Geometric Network Model (GNM); Industry Foundation Classes (.IFC); Safest Routes; Shortest Routes*

## INTRODUCTION

Nowadays, humans spend more time inside the building than outdoor activities in their daily lives (Bayat et al. 2020). Therefore, the safety factors in the building need to be taken into account, especially the emergency route that are designed for users to evacuate. According to the Fire and Rescue Department of Malaysia (BOMBA), (2018) a total of 6626 cases of structural fires were investigated and reported. 58.8% or 3893 cases happened due to short circuits incidence (BOMBA 2018).

One of the challenges during a disaster is the emergency evacuation of users through the best route to safe areas (Atyabi et al. 2019). This is because certain parties, such as outsiders entering the premises, may occasionally encounter difficulties due to the struggle to locate the exit route or the plan provided is ineffective and inefficient. According to Thill et al. (2011), the vast majority of reported research focuses only on the construction of 2D plan building routes, while various obstacle factors are not addressed.

Previous studies related to emergency routes confirm the quality of damage estimates depends on a model network that requires complete internal information typically obtained from architects, engineers and contractors and it can also be applied to Building Information Modeling (BIM) (Volk et al. 2014). According to the Building SMART & National BIM Standard (NBIS, 2007) BIM is defined as the digital characterization of the physical structure and description of functions that is a source of knowledge sharing in structures and beliefs for decision making. Furthermore, the results from the constructed model contain various object data for the extracted and analysed use (NBIS, 2015). Eastman (2011) defines BIM as a new modelling technology and a set of processes for communicating, producing and analysation of building models. Therefore, Solihin et al. (2017) said that BIM is a very valuable resource to manage development information through a lifecycle of a building.

There are plenty of research, that focuses on the BIM application that demonstrated the variety of structural components information such as floors, rooms, doors, and windows for disaster planning (Kemec et al. 2009; Liu et al. 2017). Gelido et al. (2018) built 3D model the main library of Diliman University, Philippines by using SketchUp software in a simple form without architectural engravings, because only rooms and corridors are important in making fire evacuation plans. Other than that, Xiong et al. (2017) have introduced a method that supports 3D internal route planning by taking into account some of the obstacles from the semantic 3D model that it represents as LoD City GML. Next, Liu et al. (2018) have proposed a method for extracting geometry and element characteristics from industrial foundation classes data (IFC format) for visualization of the interior of a building. However, this IFC method is also widely used in various applications, especially in emergency planning and indoor navigation (Isikdag et al. 2013; Gelido et al. 2018; Diakité & Zlatanova 2018; Nikoohemat et al. 2020).

There is a technology that is used as a medium to determine the emergency route, namely the Geographical Information System (GIS). GIS is a method that is able to analyse, store, retrieve, collect and even display data from the geography of the earth for a specific purpose. GIS has been successfully used in a variety of applications since its invention in the 1960s (Ma et al. 2017). Furthermore, there have been several previous studies that use various methods to determine emergency route planning. One of the methods used is a combination of an ant colony algorithm and network analysis that optimises the selection of emergency routes by identifying human behavior (Atyabi et al. 2019). In addition, the Dijkstra algorithm is used by taking into account the starting point and until the objective point is reached to determine the shortest route (Pramudita et al. 2019). Ahmed et al. (2017) performed the method of road network analysis in Greater Cairo by taking into account the factors of several obstacles, such as congestion and accidents that occur. The result indicates that the travel time suggested by the network analysis result of the best route are much better than the travel time of the shortest route used by the locals.

As a result of several studies mentioned earlier, the effectiveness of the method used is network analysis in GIS because it can take into account various factors, including possible obstacles on each route that may occur compared to other methods that only take into account time and distance (Zverovich et al. 2016; Xiong et al. 2017; Gelido et al. 2018). For that reason, the GIS capabilities are needed to be expanded into the indoor environment. This is because the indoor environment is way too complex as well as challenging for emergency indoor route planning (Cao & Lu 2012). Vanclooster and De Maeyar (2012) suggest that indoor route planning must consider internal networks, semantic information, and relationships between internal and external networks.

They are some efforts to integrate BIM and GIS in order to design the best route in emergency evacuation planning. The integration products enable effective information management throughout the project cycle, including planning, designing, construction, operation, and maintenance (Cui et al. 2019). BIM and GIS both interpret 3D modelling from different perspectives, which is GIS focuses on real-world modeling, whereas BIM focuses on the design process (Liu et al. 2017). Chen et al. (2014) has conducted studies using 3D geometric network model (GNM) and BIM to support the workflows for fire simulation. The use of 3D GNM is to analyse the shortest path for an emergency response while BIM is used as a 3D display that can provide geometry and attribute information. This previous study shows that the integration of BIM-GIS can offer a better result, especially in emergency route planning for indoor environments.

Therefore, this study was conducted to determine the safest and shortest path with a variety of different types of obstacles based on the scenario performed on the new evacuation route by integrating BIM into GIS to produce path distances more accurately in 3D models. Also, new routes for exits are also being determined to reduce congestion at the exit during an emergency evacuation.

## METHODOLOGY

### STUDY AREA

The Department of Infrastructure Development building located in Universiti Kebangsaan Malaysia (UKM) was selected as the study area due to the diversity of indoor arrangement structures. The Infrastructure Building which has an area of 2112 square meters located in Bangi, Selangor. The building has two emergency exits using stairs and three exit access routes, namely two on the first floor and one on the second floor.

This study focused on staff working in the Infrastructure Building. The researcher chose this building as the study location due to the closed indoor environment and difficult movement by various factors, such as the arrangement of unorganized office equipment that can be an obstacle to getting out of the building in the event of an emergency. The study area can be seen in Figure 1.

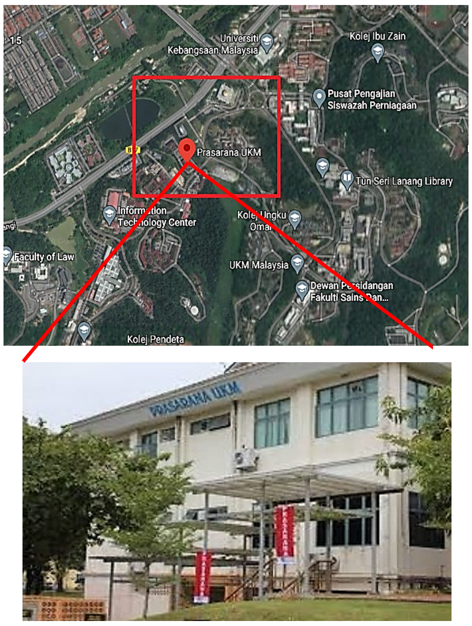


FIGURE 1. Location of Infrastructure Development building (UKM)

The general methodology of the study can be seen in Figure 2. Based on Figure 2 there are two sub-sections namely data preparation and analysis process.

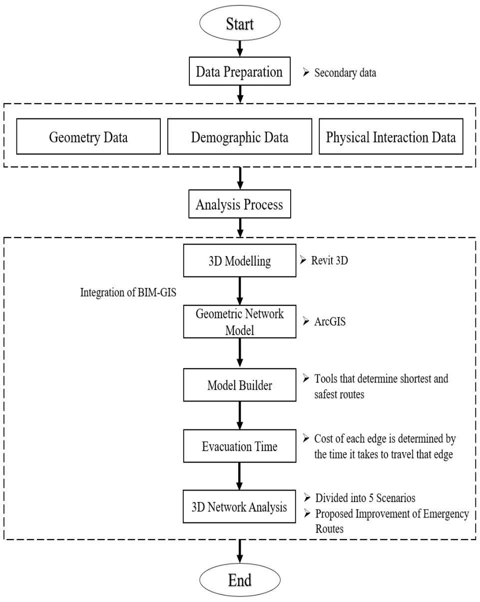


FIGURE 2. General methodology

### DATA PREPARATION

The data preparation phase is involving with the data arrangement process to ensure the study objectives is achieved. The data preparation consists of geometry data, demographic and physical interaction information which are crucial for this study.

### GEOMETRY DATA

The geometry data is a fundamental of this study. This is because, the indoor spaces data precision is required to represent the actual on site representation for the emergency route. This geometry data used in this study is developed from the architectural plan by using Revit Autodesk to optimize the use of 3D BIM model information.

### DEMOGRAPHIC DATA

The demographic data is used to determine gender and age ratio by category because it has a significant effect on the results of evacuation simulations (Chen et al. 2019). This data was obtained from the UKM infrastructure staff through interviews (Syed Abdul Rahman et al. 2020). Table 1 shows data obtained based on age and gender. Table 1 illustrates the data gathered by age and gender. It reveals that the middle-aged group includes 119 persons (76.77%) compared to the young group, which has 36 people (23.23%).

As a result, this study uses the middle-aged group as a criterion for selecting physical interaction data, such as walking speed data, so that the evaluated route is the most time-efficient.

### PHYSICAL INTERACTION DATA

One of the complex data that can affect the evacuation time is the physical interaction data. Physical interaction data were used as parameters in the study to determine the effect on transfer time. According to the study Chen et al. (2019) physical interaction data is used and applied to employees in the office according to the age range between 21 to 60 years. There are five parameters as physical interaction data shown in Table 2.

This information is used to choose a walking speed. This study focuses on middle-aged people, notably middle-aged women, based on demographic data. This is due to the fact that the data value for the lowest walking speed group is 1.20 m/s for middle-aged women. The value of shoulder width is insignificant. The other three factors, acceleration time, obstacle distance, and comfort distance, are all the same for each group. As a result, this study only used the minimal walking speed value to calculate the best time for the victim to arrive at during an emergency evacuation by taking the shortest and safest route possible, as established by the analytical simulation.

TABLE 1. Statistics for gender and age groups

| Age Range | Age Group | Male | Female | Total |
|---|---|---|---|---|
| 14-35 | Young | 27 (22.31%) | 9 (26.47%) | 36 (23.23%) |
| 36-64 | Middle-Aged | 94 (77.69%) | 25 (73.53%) | 119 (76.77%) |
|  | Total | 121 (78.06%) | 34 (21.92%) | 155 (100%) |

*Source*: Rahman et al. (2020)

TABLE 2. Parameter based on specific user categories

| Categories | Young Female | Young Male | Middle-aged Female | Middle-aged Male |
|---|---|---|---|---|
| Speed of walking (m/s) | 1.27 | 1.32 | 1.2 | 1.25 |
| Width of Shoulder (cm) | 38 | 41 | 39.5 | 41.9 |
| Acceleration time (s) | 1.1 | 1.1 | 1.1 | 1.1 |
| Distance to obstacle (m) | 0.15 | 0.15 | 0.15 | 0.15 |
| Comfortable distance(m) | 0.08 | 0.08 | 0.08 | 0.08 |

*Source*: Chen et al. (2019)

## ANALYSIS PROCESS

### 3D Modelling

This process is initiated on a 2D plan so that it will be displayed as a 3D shape that can generate geometry and semantic information. The data and layers of objects that are built are very important because it will be used during the next process which is the process of designing geometric networks in ArcGIS software. The 3D model building and floors were constructed using Revit 2020 software with reference to geometric data obtained in the form of floor plans. The 3D model only takes into account components such as floors, stairs, walls and doors. This is because such components are considered essential for building emergency routes. The 3D Modelling of Infrastructure Building UKM can be seen in Figure 3. Figure 4 shows the cross sections of the components such as floors, stairs and others at each level in the Revit software.

FIGURE 3. 3D Modelling Infrastructure Building UKM

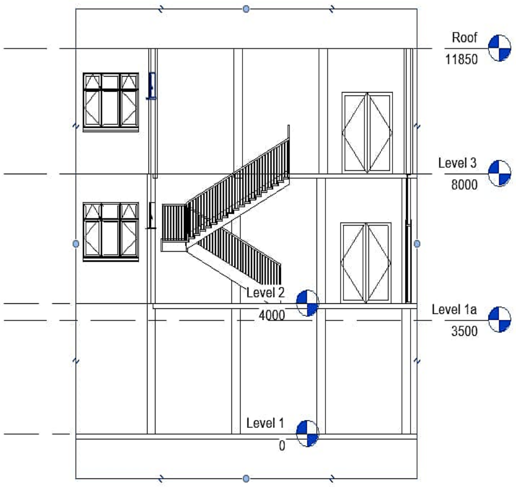


FIGURE 4. A cross section of the components

### Integration of BIM-GIS

The generated 3D BIM model was converted to IFC (Industry Foundation Classes) format to enable the data interoperability through IFC standard. After data format conversion (.IFC), the data interoperability connection needs to be activated first before starting the quick import. This purpose is due to transfer the data to multipatch geometry (.shp). The geometry parameters and IFC readings in this quick import process can be set according to user requirements. The constructed 3D BIM model in the IFC standard is then integrated into the 3D GIS environment through the proposed method by Syed Abdul Rahman and Abdul Maulud (2019) by converting the BIM model (.rvt) to Multipatch Shapefile (.shp) via the FME environment (Workbench) to minimize the geometric and semantic information loss during the integration process. Figure 5 shows the method process for integrating BIM to GIS.

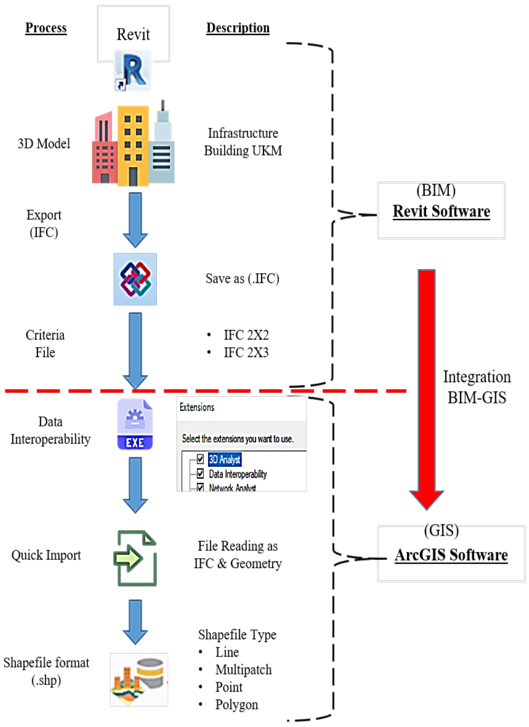


FIGURE 5. BIM-GIS Integration Method

## Geometric Network Model (GNM)

The beginning of this process is the basic selection of objects planned to be included in ArcScene, such as paths in buildings and stairs to be used as lines. Then, the geo-reference coordinate data needs to be determined to generate the values of the x, y, and z axes so that the calculation between the distance and the node is accurate. The geodatabase for this infrastructure building model is divided into three feature classes and contains feature dataset data. The constructed feature classes include network grids, markers, and polygons. This is intended to connect each path into nodes and edges. Nodes will represent units of space within the infrastructure building and also connect paths, while edges represent distances. Figure 6 shows the overall geodatabase structure of the infrastructure building together with the data set built.

The GNM model was used in this study due to its suitability in identifying the shortest and safest path for the indoor environment. To build a GNM model, the indoor space's geometry of the Infrastructure Building UKM was converted into nodes where each node represents each commercial unit, corridor and staircase. Figure 7 shows the developed GNM after the data set features from the BIM model have been converted.

## Model Builder

The model builder is shown as a diagram, flow chart, or workflow that connects a network of process sequences and as a geoprocessing tool that connects the output from one process to the input process for another process. The Make Route Layer, Add Location, Solve and Apply Symbology from ArcCatalog tools were applied to identify the suitable route for the study area. The route layer is constructed using the impedance attribute as a parameter consisting of shortcut data and a network grid to produce a model route layer. Then connected to the input location parameter which is Add Location. This input location parameter has various types of sub layers among which are stop layer, point barrier, line barrier, and polygon barrier. However, the sub layer used in this input location parameter is the stop layer. This is because, the stop layer has the appropriate specifications to be used as a fire barrier in this study. Finally, the use of this symbolic layer can be used for the symbolic selection of other objects such as start and end points, emergency doors and fire pits. Colour selection is done in this symbolism to distinguish safe routes and shortcuts, in which safe routes are green while shortcuts are blue. Figures 8 and 9 depict flow charts for the shortest and safest routes, respectively while Table 3 shows the use of parameters in the Model Builder.

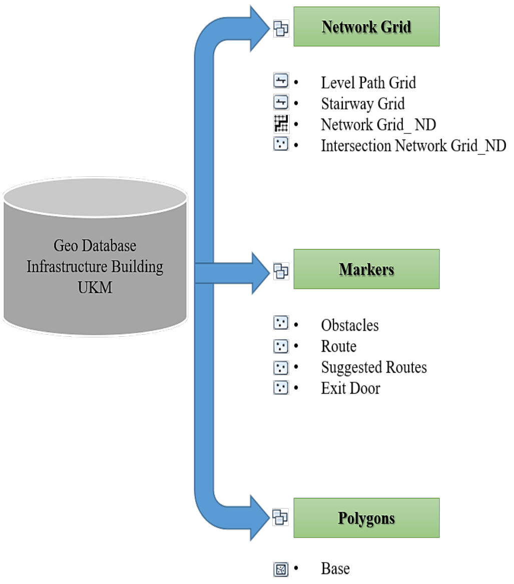
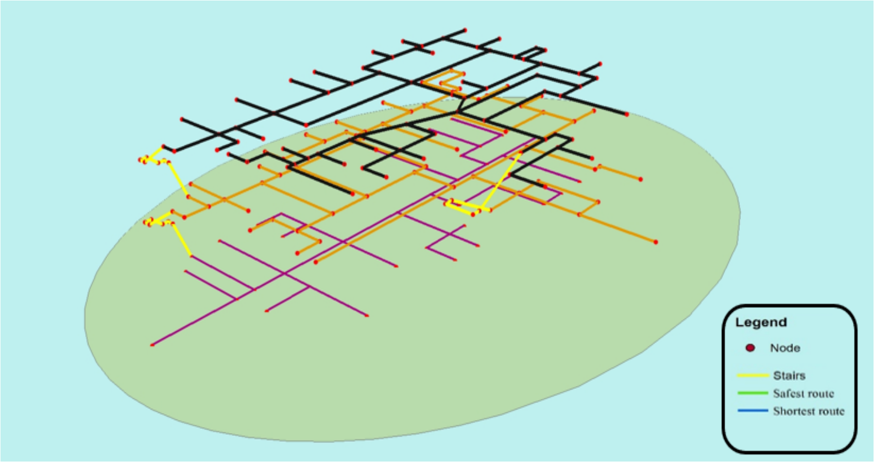


FIGURE 6. Geodatabase, Feature Classes and Feature Set Data



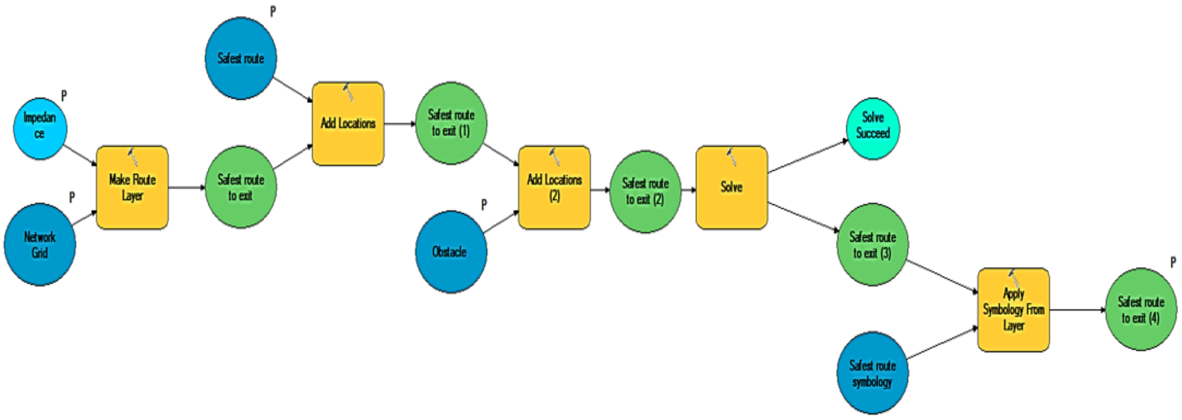


FIGURE 8. Safest route flow chart using model builder

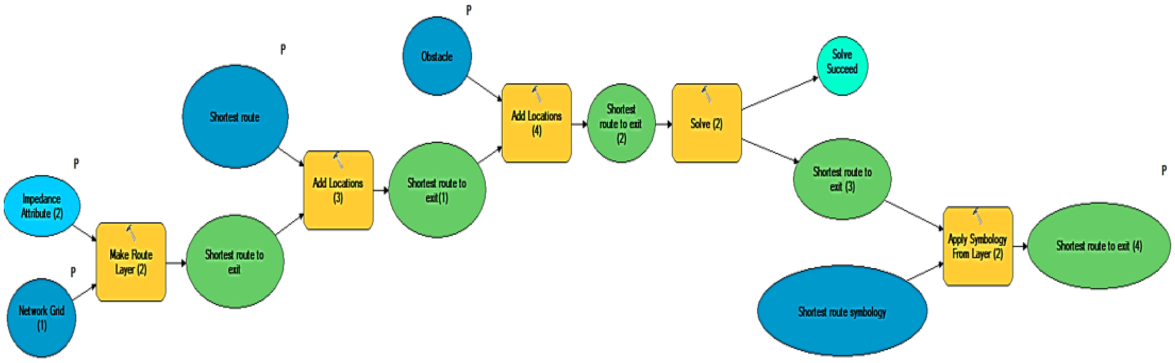


FIGURE 9. Shortest route flow chart using model builder

TABLE 3. Use of parameters and functions in the Model Builder

| Parameter | Type | Function |
|---|---|---|
| Input Network Analysis | Network data set layer, input parameters | The height of the model using the geometric Z coordinate value. |
| Barrier | String, parameter input | List of network data set constraint attributes. |
| Attribute Impedance | String, parameter input | The cost attribute is the calculation of the shortest path. |
| Path layer | Tool | This function builds a path analysis layer. This layer contains data and properties that determine how the best route will be calculated, as well as the calculated results |
| Route | Network analysis layer | It serves as a layer of path analysis |
| Add Location | Tool | The addition of a network location to the network analysis layer aims to add stops to the route layer. |
| Stop Input | Characteristics set (points), parameter input | To identify the characteristics that will be traversed by the resulting path. |
| Route (1) | Network analysis layer | Route layer with stops |
| Solving | Tool | Calculate which route has less cost. |
| Successful solution | Boolean | Indicates whether the solution operation is successful or not, |
| Route (2) | Network analysis layer | The path layer contains the generated path. |
| Output Symbology Path | Layer | The symbology of the layer tool applies the symbology of this layer to the exit path layer. |
| Applying Symbology from Layers | Tool | Applies the symbology from the layer referenced by the output symbology path variable to the output path variable. |
| Output Layer | Network analysis layer, issued parameters | Path layer that contains a predefined symbology from the output symbology. |

### Evacuation Time

The evacuation time will be determined based on the selection of the start and end nodes according to the scenarios that have been determined. Input speed will be included in the attribute value for the shortest and safest route. Speed of walking on horizontal indoor floors and speed of vertical stairs should be considered when determining evacuation time. The cost of each edge is determined by the time it takes to travel that edge, which can be calculated using the equation:

$$t_e = \frac{D_e}{S_e} \tag{1}$$

Where

$t_e$ = time transverse edge

$D_e$ = distance of the edge

$S_e$ = speed transverse edge

The network's travel speed is estimated to be 1.20 m/s for horizontal speed and 0.8 m/s for vertical speed when taking the stairs. The shortest and safest routes between the two points will be calculated using 3D network analysis along with the cost based on Equation (1). Each route with a minimum amount of evacuation time is based on Equation (2).

$$T = \sum_{i=1}^{\infty}\left[\left(\frac{\mathrm{D_{horiz.}}}{\mathrm{S_{walking}}}\right) + \left(\frac{\mathrm{D_{vertic.}}}{\mathrm{S_{stair}}}\right)\right] \tag{2}$$

Where

T = time transverse edge

$D_{horizontal}$ = distance of the edge

$S_{horiz}$ = Walking speed horizontal

$D_{vertic}$ = Distance vertical

$S_{vertical}$ = Walking speed vertical

## RESULT AND DISCUSSION

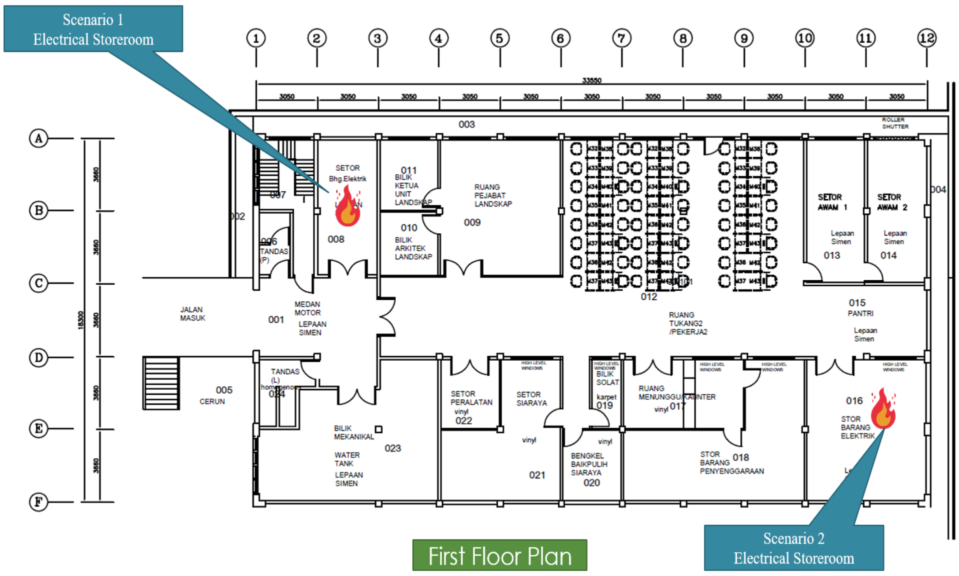
### 3D NETWORK ANALYSIS

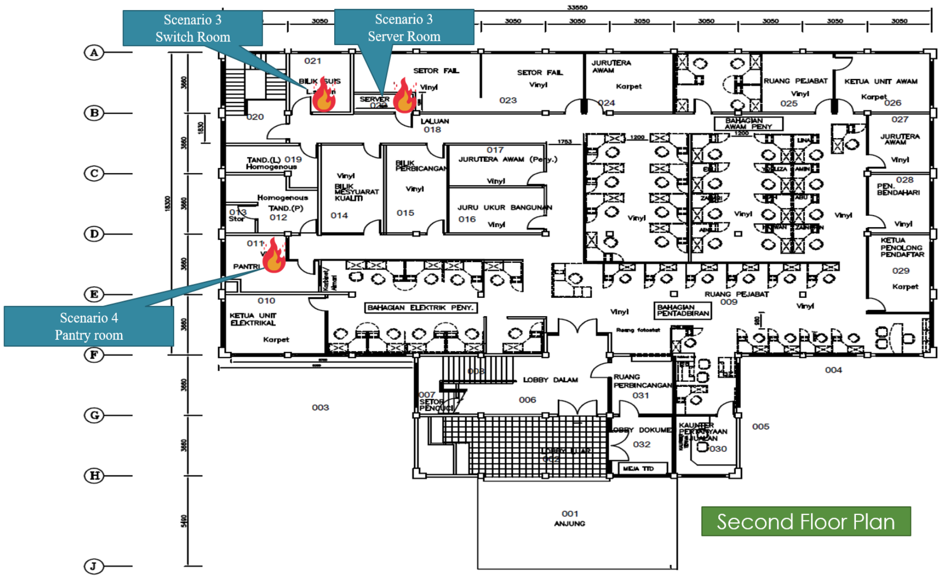
There are five (5) scenarios implemented to determine the shortest and safest routes. These scenarios are divided according to each floor of the Infrastructure Building. In addition, to evaluate the capability of this determined route method, an analysis is performed based on the obstacles that occur for each scenario in the infrastructure building. The obstacle selected in this simulation study is fire because the probability of fire in the building is higher than other obstacles.

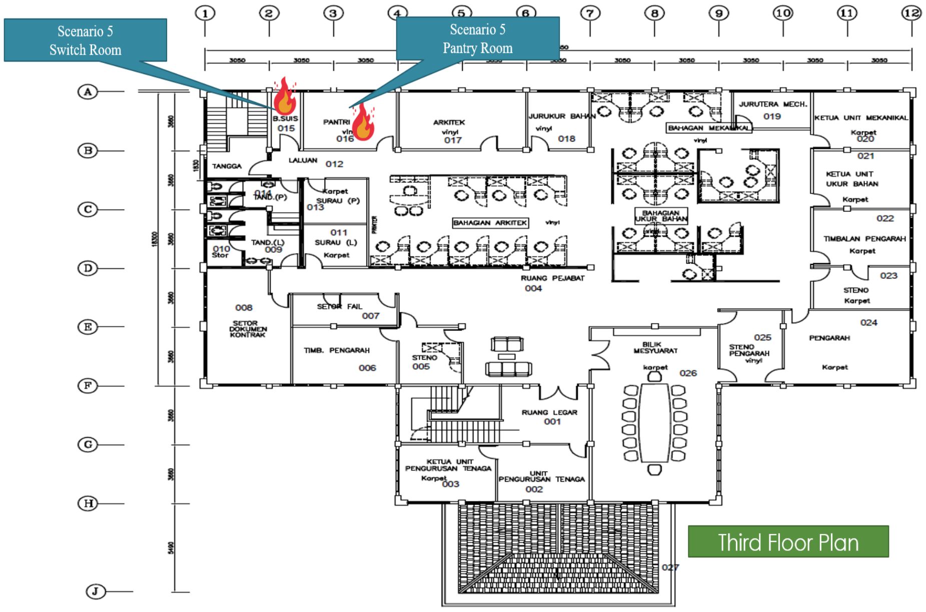
Among the fire risk factors that are taken into account in the Infrastructure Building are such as in the server room, pantry room, switch room, and storage of electrical appliances. This is due to the occurrence of short circuits because of cracks in cable insulation, overload flow, leakage of electrical current due to damage to cables or insulation and negligence in the operation of electrical appliances such as water heaters. There are several scenarios as well as starting locations shown in Table 4. Figure 10 shows the plan for each level of the infrastructure building in order to give a clear picture of the location of the obstacles for each of the scenarios that have been determined.

TABLE 4. List of scenarios and starting location

| Scenario No. | Start point |
|---|---|
| 1 | Between office space and the equipment store on the first floor |
| 2 | Outside the electrical store facing the public store room on the first floor |
| 3 | Outside the male toilet faces the switch room on the second floor |
| 4 | Outside the female toilet faces the pantry room on the second floor |
| 5 | Outside the prayer room and the female toilet faces the switch room and pantry on the third floor |







Scenario 5
Switch Room

Scenario 5
Pantry Room

Third Floor Plan

FIGURE 10. Plan of each level and location of obstacles for each scenario

### SCENARIO NO.1

The first scenario assumes a fire breaks out in the electrical storeroom on the first floor. The starting point for the shortest and safest routes starts at node number 77 located between the landscaped office space and the store. This route will end at node number 1 which is through the open route on the first floor for the shortest while the safest route will end at the exit located on the first floor which is node number 136. Victims who are on the first floor who use the shortest route have to traverse a distance of 15.5 meters to reach the open route while if the victim uses the safest route, the distance to be travelled is 21.8 meters. The shortest route takes 12.9 seconds to evacuate, while the safest route takes 18.2 seconds. Figure 11 shows the outcome of Scenario No.1.

### SCENARIO NO. 2

The second scenario is the same as the first scenario which is assumed that a fire breaks out in the electrical storeroom but a different location which is at node number 172. The starting point for the shortest and safest routes starts at node number 158 located between the office space and the equipment store. This route will end at node number 1 which is through the open route gate on the first floor for the safest route while the shortest route will end at the exit on the first floor which is node number 136. Victims who are on the first floor using the shortest route have to travel a distance of 13 meters to reach the exit while the safest route, the distance to be travelled is 31.8 meters. The shortest route takes 10.88 seconds to evacuate, whereas the safest route takes 20 seconds. Figure 12 shows the outcome of Scenario No.2.

### SCENARIO NO. 3

The fire case in this third scenario is assumed to occur in the switch and the server room respectively. The starting point for the shortest and safest route starts at node number 34 located outside the men’s toilet opposite the switch room on the second floor. This shortest and safest route will end at node number 1 which is through the open route on the first floor. Victims who are on the second floor who use the shortest and safest route have to travel a distance of 27 meters to reach the open route. This shortest and safest route has an evacuation time of 26.1 seconds. Meanwhile, if using the main entrance route on the second floor has a long evacuation time of 33.1 seconds. Figure 13 shows the outcome of Scenario No.3.

### SCENARIO NO. 4

This fourth scenario assumes that the fire breaks out in the pantry room located on the second floor. The starting point for the shortest and safest starts at node number 40 located outside the female toilet opposite the pantry room on the second floor. This route will end at node number 1 which is through the open route on the first floor for the safest route while the shortest route will end at the main entrance route located on the second floor which is node number 111. The victim who is on the second floor who uses the shortest route has to traverse a distance of 30.2 meters to reach the main entrance route while for the safest route, the distance to be travelled is 58.1 meters. This shortest route has an evacuation time of 25.2 seconds while the safest route requires an evacuation time of 52 seconds. Figure 14 shows the outcome of Scenario no.4.

### SCENARIO NO. 5

This fifth scenario is located on the third floor and the fire is assumed to have occurred in the switch and the pantry room respectively. The starting point for the shortest and safest route starts at node number 51 which is located outside the prayer room and the female toilet facing the switch and pantry room on the third floor. This route will end at node number 1 which is through the open route on the first floor for the shortest while the safest route will end at the main entrance route located on the second level which is node number 111. Victims who are on the third floor who use the shortest have to travel a distance of 42.37 meters to reach the open route on the first floor while for the safest route the distance to be travelled is 57.5 meters to reach the main entrance on the second floor. The shortest route takes 42.5 seconds to evacuate, while the safest route takes 51.5 seconds to evacuate. Figure 15 shows the outcome of Scenario no.5.

Table 5 shows the overall data results obtained from the scenarios performed. The comparison of shortest and safest routes in Table 4 shows that 80% of the situation, namely scenarios 1,2,4, and 5, have a long distance for safest routes compared to shortest routes. This is because, Equation (2) used in this study shows that the evacuation time is influenced by the speed and distance of the path. While 20% of the scenario that is scenario 3 has the same time and distance for shortest and safest routes because they have the same starting and end points in this scenario.

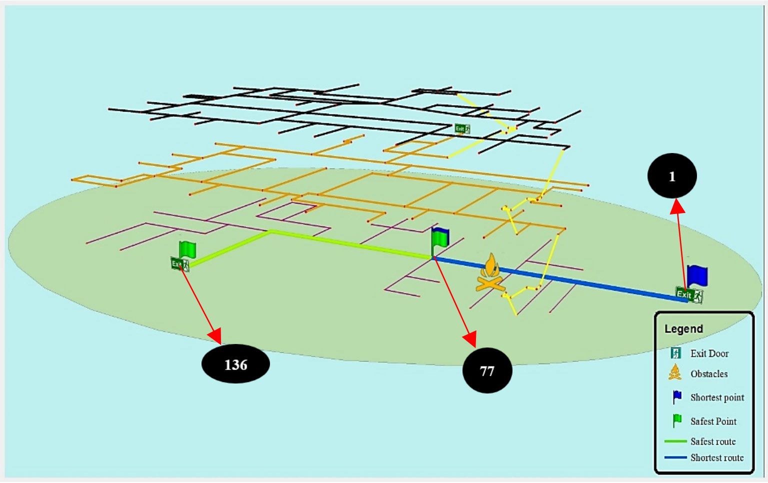


FIGURE 11. The shortest (blue) and safest (green) routes on first floor for Scenario No.1

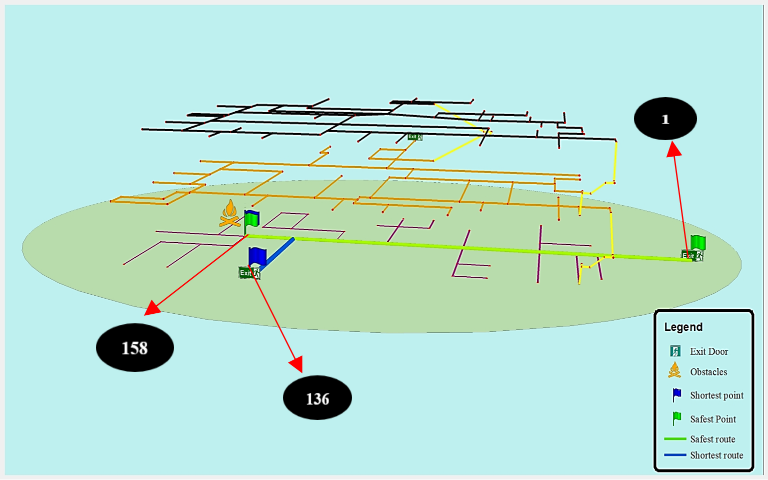


FIGURE 12. The shortest (blue) and safest (green) routes on first floor for Scenario No. 2

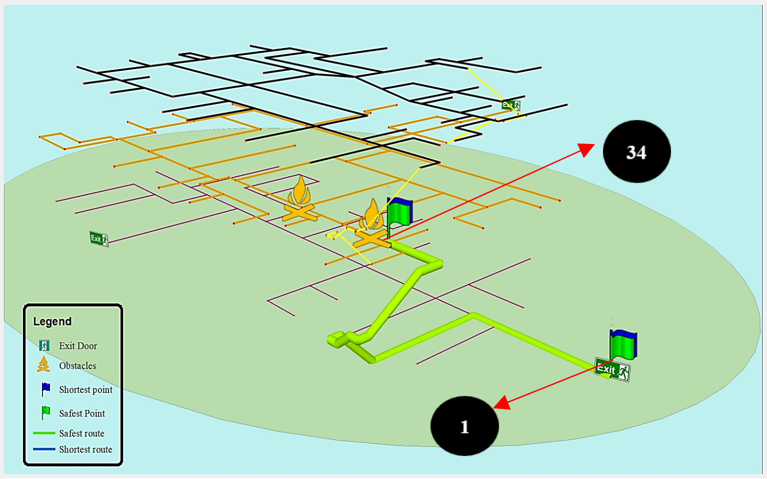


FIGURE 13. The shortest (blue) and safest (green) heads towards the exit on the first floor for Scenario No.3

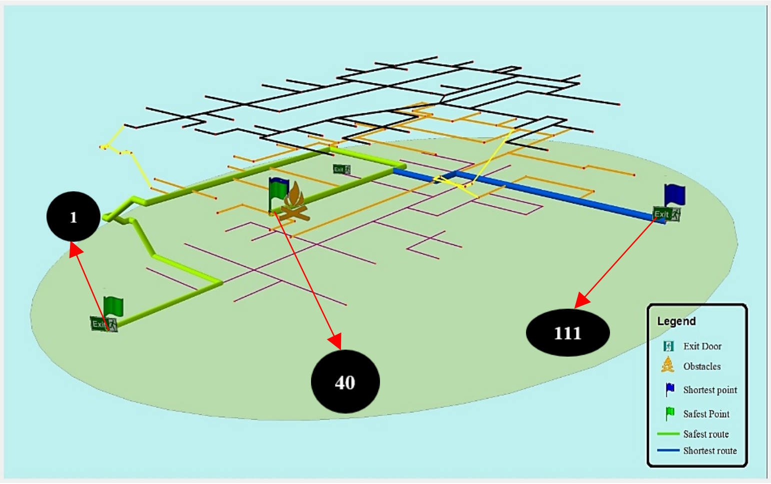


FIGURE 14. The shortest (blue) and safest (green) heading in a different exit direction for Scenario No.4.

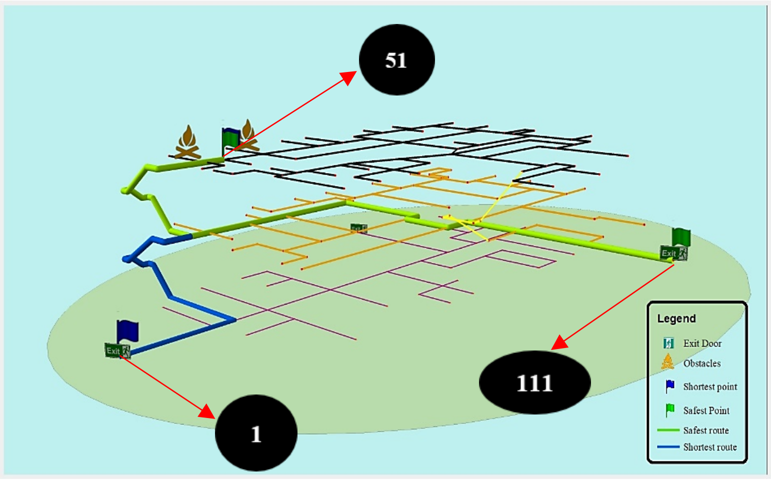


FIGURE 15. The shortest (blue) and safest (green) heading in a different exit direction for Scenario No.5

TABLE 5. Comparison table between the results of safest and shortest routes for each scenario

| Scenario | Shortest Route | | Safest Route | |
|---|---|---|---|---|
| | Evacuation time (seconds) | Length (meter) | Evacuation time (seconds) | Length (meter) |
| 1 | 12.9 | 15.5 | 18.2 | 21.8 |
| 2 | 10.8 | 13.0 | 20.0 | 31.8 |
| 3 | 26.1 | 27.0 | 26.1 | 27.0 |
| 4 | 25.2 | 30.2 | 52.0 | 58.1 |
| 5 | 42.5 | 42.37 | 51.5 | 57.5 |

### PROPOSED IMPROVEMENT OF EMERGENCY ROUTES

For the proposed improvement of the emergency route the outcomes for this section of the proposed study route are shown in Figure 16 and Figure 17 which are the proposed exits on the third and first floors respectively. Figure 16 shows the proposed exit route generated in the first-floor space. According to the findings of this analysis, the route taken is on the first floor. The starting point for the shortest and safest routes starts at node number 158 located between the public store and the maintenance store. This route will end at node number 136 which is through the exit on the first floor for the safest route while the shortest will go through the proposed exit route which is located on the first floor which is node number 194.

Victims who are on the first floor using the shortest have to travel a distance of 7.12 meters to reach the proposed exit door on the first floor while for the safest route, the distance to be travelled is 13.06 meters to reach the exit on the first floor. The shortest route takes 5.93 seconds to evacuate, while the safest route takes 10.8 seconds to evacuate. Meanwhile, if the safest route uses the same route as in scenario two, the evacuation time will be 20.0 seconds. Therefore, researchers suggest for the safe route is also altered.

Figure 17 shows the emergency route generated on the third floor. The results of this analysis show that the routes used are the routes that are on the third floor and first floor. The shortest and safest route begins at node 51 which is located outside the prayer room and the female toilet facing the switch room and pantry room on the third floor. This route will end at node number 1 which is through the open route on the first floor for the safest route.

Next, is the shortest for the proposed route located at node number 134 near to the mechanical section on the third floor. The proposed direction of this route will use the outer stairs to reach the first floor. The study's findings show that the shortest route for new evacuation time is 17.0 seconds with a distance of 20.4 meters, while the safest route requires 42.5 seconds with a distance of 42.3 meters.

Table 6 shows the results of the data obtained from the comparison of the shortest and safest route proposed based on scenarios 2 and 5. In addition, this table compares the data in terms of evacuation times and emergency route distances before and after recommendations for safe and shortcut routes. The results of the comparison of the shortest before and after the second scenario, show that the reduction can be done from 10.8 seconds to 5.9 seconds. The difference in the second scenario shows a reduction of 4.9 seconds or a percentage of 45.37%. Moreover, for the safest route a reduction can also be done which is. by 9.2 seconds or a percentage reduction of 46%. Next, the shortest route before and after the fifth scenario can only be taken until the proposed exit route only which is 17 seconds and no comparison can be made because the calculation of this time is only calculated until the proposed exit route is on the third floor only. As for the safest route proposal, the evacuation time can be reduced by 9 seconds or in a percentage of 17.48%

TABLE 6. Result of a proposed route for Shortest and Safest

| Scenario | Proposed Route | Shortest Route | | Safest Route | |
|---|---|---|---|---|---|
| | | Evacuation time (seconds) | Length (meter) | Evacuation time (seconds) | Length (meter) |
| 2 | Before | 10.8 | 13.0 | 20.0 | 31.8 |
| | After | 5.9 | 7.12 | 10.8 | 13.0 |
| 5 | Before | 42.5 | 42.3 | 51.5 | 57.5 |
| | After | 17.0 | 20.4 | 42.5 | 42.3 |

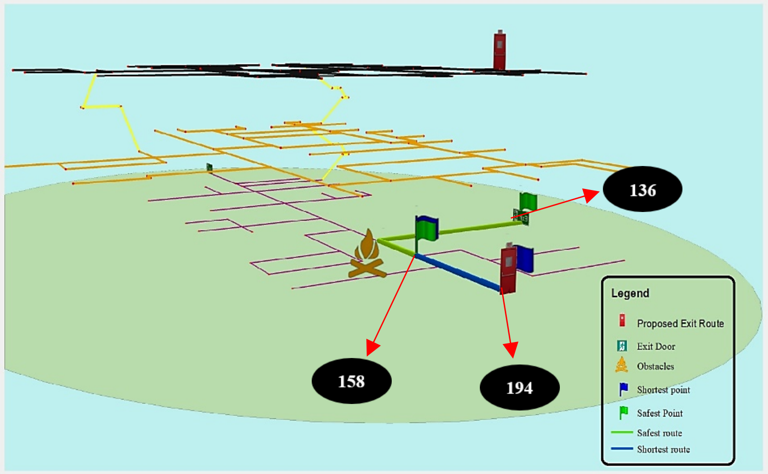


FIGURE 16. Proposed Exit on First Floor

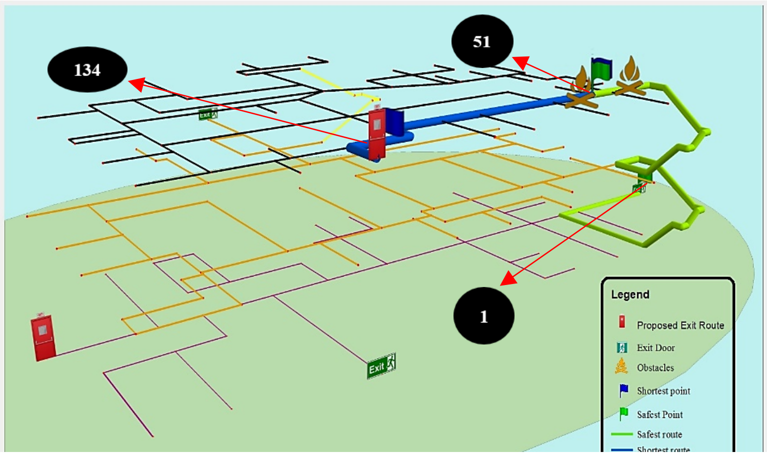


FIGURE 17. Proposed Exit on Third Floor

## CONCLUSION

In this study, to find the safest and shortest approach in this study, several processes must first be completed, such as data preparation and data analysis. Furthermore, the Building Information Model (BIM) that was used in this study was to create a 3D model of the Infrastructure building using 3D Revit software. The production of this 3D model resulted in the provision of crucial components such as floors, stairs, walls, and doors to create the building's interior views. After that, a Geometric Network Model (GNM) is created using the BIM-GIS integration method. This method begins when the 3D building model has been completed. The file format must be changed to (.ifc) and then to multipatch shapefile (.shp) before it can be used with ArcGIS software. This kind of integration is critical for precisely producing the safest and shortest routes, as well as conducting an analysis that takes into account a variety of obstacles based on the conditions on each route built. Model Builder tools are also utilized in ArcGIS software to assess safe routes, short routes, and barriers, as well as to include the horizontal and vertical speeds, which are 1.20 m/s and 0.8 m/s, respectively. The creation of safe paths is based on a number of factors, including fires caused by human negligence, technical issues, and locations with a high risk of fire, according to figures given by the Fire and Rescue Department of Malaysia. Then, based on the emergency evacuation time and route distance, the short and safe routes will be compared.

The result of the comparison between shortest and safest routes in Table 5 shows that 80% of the situation, namely scenarios 1,2,4, and 5, have a long distance for safest routes compared to shortest routes. This is because equation (2) used in this study shows that the evacuation time is influenced by the speed and distance of the path. While 20% of the scenario that is scenario 3 has the same time and distance for the shortest and safest routes because they have the same starting and end points in this scenario. Other than that, the result of a proposed route for the shortest and safest based on scenarios 2 and 5 has also been done. The results of the comparison of the shortest before and after the second scenario, show that the reduction can be done from 10.8 seconds to 5.9 seconds. The difference in the second scenario shows a reduction of 4.9 seconds or a percentage of 45.37%. Moreover, for the safest route, a reduction can also be done which is. by 9.2 seconds or a percentage reduction of 46%.

For future research, it is suggested that in addition to considering congestion at exits, corridors and stairs. This is because the shortest and safest routes do not reflect the possibility of problems occurring, such as congestion when an emergency evacuation occurs. Other than that, predictions of human behaviour during an emergency evacuation can also be made using machine learning methods. This is because taking a long evacuation time is one of the reasons for human behaviour itself during an emergency.

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## DECLARATION OF COMPETING INTEREST

None

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