Analysis of the effectiveness of evacuation paths in terms of mall visitors evacuation speed (Case Study: Mall Palladium)

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Abstract. The Mall is a shopping center that focuses on a department store consisting of retail and restaurants with the shop typologies facing a corridor that serves to connect all shops. Generally, a mall has three floors or more and has various human activities inside. Fire Protection System is a system consisting of equipment, supplementary, and facilities in building to protect the building and their environment against fire disaster. Fire Passive Protection System can prevent mortality and fatal damage to the building so that the security and safety of the mall users will be more secure. Evacuation is a way to survive from the dangers that happened around so that the components to support evacuation must be well maintained. The observation method is used to determine the effectiveness of the evacuation path based on the speed of evacuation of the user and to determine the current condition. The simulation method uses Arena software that is used to determine the speed of evacuation of occupants (in this case, Case Study: Palladium Mall). The final results of this study are in the form of recommendations for the design of evacuation lines that are optimal for fire protection in buildings.

1. Introduction

The development of the city in Medan affects the increase in buildings, both tall buildings and buildings with a height of 1 floor or more. Generally 2 store buildings are dominated by residential buildings (housing), shop houses (shop houses), office houses (rukan), factories (industrial buildings), While parts of tall buildings appear buildings such as malls, apartments, and hotels. The mall building has elements that make it easy for the fire to spread quickly so fire protection is needed to support the evacuation process. The Fire protection system is a system consisting of equipment, equipment, and facilities in a building to protect buildings and their environment from fire hazards. Passive Fire Protection System must be present in every building, especially tall buildings that function to prevent fatalities and fatal damage to buildings so that security and safety of occupants will be more guaranteed. which is good for building occupants. Evacuation Route is a special lane that is connected to all parts of the building that is used to save themselves to a safe area (Gathering Point). So that components to support the evacuation route must meet standards to be effective when an emergency occurs.
1.1 Problems Encountered
In the formulation of this problem outlines
A. How is the effectiveness of evacuation routes in palladium buildings viewed from the speed of visitor evacuation?
B. What are the design recommendations that can be used to speed up the evacuation process?

1.2 Research purposes
The purpose of this study is to analyze whether the evacuation route at the mall meets the standards to speed up the evacuation process.

1.3 Benefits of research
The benefits of this research are the results of the study can be used as a learning tool in finding the cause of problems or failures that occur in a building so that it will facilitate the search for alternative solutions to those problems. And research results can also be made as a means to develop strategies for conducting the same research.

2. Literature Review
2.1 Understanding emergency conditions
The emergency is a condition that occurs suddenly which is caused by natural factors, non-natural factors, and human factors. These conditions generally have a negative impact on the surrounding environment, disrupt existing activities, organizations, communities that are active at the time, and cause casualties or damage to both humans and property (BASARNAS, 2014). Emergency conditions are usually caused by 3 factors namely Natural Disasters, technical failures, riots.

2.2 Definition of building
According to the Law of the Republic of Indonesia, NUMBER 28 of 2002 Building is a physical form or the result of construction work that is on and in the ground, which functions as a place for people to carry out activities.

2.3 Definition of evacuation
An act of moving people who are affected by a disaster or who are close to a dangerous area to a safe place and away from the dangerous zone with the aim that victims or people are not affected by the disaster. From the above statement, the meaning of evacuation is a direct and rapid transfer so that people stay away from threats or danger.

2.4 Definition of evacuation paths
In the Minister of Public Works Regulation NUMBER: 26 / PRT / M / 2008 Evacuation Route is the path that leads from inside the building to a safe place. Evacuation routes must be supported by good elements so that the time for evacuation is more effective
a. Evacuation route elements:
1. Corridor, Corridor is a circulation path that plays an important role in shopping center buildings, the corridor functions as a bridge that connects a room to another room
2. Exit Sign Size
3. Signage, Emergency exits/access must be marked to facilitate evacuation in the event of a fire.
4. Emergency Stairs, Every emergency staircase in buildings of 5 floors or more, must be able to connect all floors starting from the bottom floor, except the basement to the top floor, must be made without opening (opening) except a single entrance on each floor and the exit on the floor bottom must lead to an open place.
5. Evacuation Time, the minimum evacuation time required for a mall building is 3 minutes. Mileage is measured from every point in the building to a safe place. Mileage greatly
determines the speed at which a person reacts and moves to save himself and the speed of fire to impede his journey.

2.5 Understanding mall

The mall is a closed building that is generally more than 5 stories high, with interior and exterior that is professionally designed, and good and organized air management so that visitors can carry out activities comfortably. According to Nadine Beddington Mall has several types, based on service scale:

a. Local shopping center
b. District shopping center
c. Regional shopping center

According to the location and consument target:

a. Pasar
b. Shopping Street
c. Shopping Center
d. Department Store
e. Supermarket
f. Superstore
g. Hypermarket
h. Shopping Mall
i. Town Square

3. Method

3.1 Research sites

Grand Palladium is a building that is a mall in the center of Medan, on Jl. Captain Maulana Lubis No.8, Petisah Tengah, Medan Petisah, Medan City, North Sumatra 20112, health insurance to this mall is one path and for its own achievement has several routes that can be accessed via Jl. Gatot subroto, Jl. S. Parman, Jl. Borobudur Temple, Jl. Prambanan, and Jl. Court.

![Figure 1. Location](image1)

![Figure 2. Aryaduta Hotel Building](image2)

This mall has 7 floors, the mall building is adjacent to the Aryaduta Hotel and 2 buildings are connected by its sky park parking lot, sky park is part of the Aryaduta Hotel building, except that mall visitors can park their vehicles in Aryaduta's sky park. The object examined by researchers is palladium mall.
3.2 Research methods
The location of the study was determined purposively or intentionally because at the Palladium Mall there was an earthquake in 2008 and caused some damage to this part of the building. This proves that the structure of the Palladium Mall began to experience problems. According to a company engaged in the field of construction (SUCOFINDO) Earthquakes also affect the condition of building elements such as columns and beams. With this research, it is hoped that they can be put in to face similar hazards by providing better and optimal evacuation routes to ensure the safety of building occupants. Data was collected using the Observation Method and Simulation Method.

3.3 Research Stages
The intended stage is the research design that will be carried out in stages, detailing all the stages that will be carried out in the study. The stages that will be carried out are divided into 2 stages:

1. Preparation, Formulating background, problems and objectives of the study, Gathering comparisons that discuss theories related to research, Planning stages of observation and field measurements to obtain prime data
2. Implementation, Observing and measuring using research tools, to get existing data, Performing simulations using Rockwell Automation Arena software using existing data that has been collected, Arranging all the results of reports and discussions that have been obtained from data processing then conclusions are drawn to answer the problem studied

3.4 Data analysis method
After getting the data from the research, the next step is processing the data using descriptive method by comparing the existing conditions and SNI and also the theory. Before evaluating the data, it is necessary to observe to analyze the activities of mall visitors. Data from observations will then be simulated in the Rockwell Automation Arena Software.

3.5 Introduction to software
The software used is Arena software, which is a simulation software, which in the Software we can create an experimental model by placing a process module that represents the design process that was created earlier. Arena Software can simulate various types of operations such as time of movement, operator optimization and telephone lines in a call center, setting the flow of food manufacturing in a restaurant, designing a gold mine. Researchers use Arena Software because one of the functions of the software is to simulate the time of movement, which is meant is the time of movement of residents from inside the building to outside the building.

3.6 Make an evacuation route
Based on the results of observations from the field it will be able to get a route that will be passed by mall visitors, the route can be made using a mall floor plan.

3.7 Calculate individual speed
Calculation of speed per individual mall visitors can be done using the formula NFPA 1996 (Method to Calculate the Travel Time).

3.8 Calculating visitor density
To find out the speed of people moving in a location, it is necessary to know the number of mall visitors density, which can be calculated using the formula, the number of mall visitors in the area of the mall evacuation route: \( D = \frac{p}{m^2} \).
### 3.9 Speed standard table

**Table 1.** Standard of each variable to the condition and type of facility

| Type Of Facility | Condition | Density | Speed Of Person |
|------------------|-----------|---------|-----------------|
| **Stairs (down)**| Low       | <1,9    | 1,0             |
|                  | Optimum   | 1,9 > 2,7 | 0,50           |
|                  | Moderate  | 2,7 > 3,2 | 0,28           |
|                  | Crush     | 3,2>    | 0,3             |
| **Stairs (up)**  | Low       | <1,9    | 0,8             |
|                  | Optimum   | 1,9 > 2,7 | 0,4             |
|                  | Moderate  | 2,7 > 3,2 | 0,22           |
|                  | Crush     | 3,2>    | 0,10            |
| **Corridors**    | Low       | <1,9    | 1,4             |
|                  | Optimum   | 1,9 > 2,7 | 0,7             |
|                  | Moderate  | 2,7 > 3,2 | 0,39           |
|                  | Crush     | 3,2>    | 0,18            |
4. Result and discussions

4.1 Analysis of Supporting Evacuation Elements

Table 2. Types of facilities, standards, and theories

| NO | VARIABLE | THEORI | EXISTING | VARIABLE PROBLEM | VALUE |
|----|----------|--------|----------|------------------|-------|
| 1  | Mileage to Exit | The distance to the fire ladder from any point in the effective space, a minimum of 25 m and a maximum of 45 m | The average maximum distance of each floor is above 50 meters | The maximum number of trips to exit exceeds the standard | Bad |
| 2  | Corridor Size | Corridor height is not less than 2 meters, and has a width of 1 or more | Corridor height of 3 meters, width of more than 1 meter | Each floor has different widths | Good |
| 3  | Number of Emergency Stairs | Buildings that have more than 3 floors must have 2 or more emergency stairs | On the 2nd floor there is only one emergency staircase that can be accessed, the other 2 stairs can only be accessed from the 3rd floor cinema and the second floor | The stairs for evacuating are still lacking even though there are more than 2 stairs | Bad |
|   | Emergency ladder width | The minimum width for a fire escape is 1.2 meters | The width of one of the emergency stairs, from the 3rd floor to the 1st floor is only one meter | Some emergency stairs still do not have a width according to the standard |
|---|------------------------|-----------------------------------------------|-------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------|
| 4 | Emergency ladder width | The minimum width for a fire escape is 1.2 meters | The width of one of the emergency stairs, from the 3rd floor to the 1st floor is only one meter | Some emergency stairs still do not have a width according to the standard |
| 5 | Form of emergency stairs | Stairs should not be spiral or round | The stairs are not circular in shape | Good |
| 6 | Exit emergency stairs | The exit on the ground floor must go outside the building | Each exit is at Groundfloor and does not lead outside the building, although indeed every fire door is close to the entrance, so they expect the evacuation victims to run to the entrance | Exit on each emergency stairs do not go outside the building | Bad |
In the table above we know that the standard of support for evacuation routes at the Palladium Mall is still at an average level, and also the most important thing in the evacuation process is providing a gathering point. Palladium Mall does not have a gathering point, the mall wants evacuation victims to evacuate to the front building that directly leads to the highway.

### 4.2 Discussion

From some of the tables above, we can conclude that the evacuation route elements in the Palladium Mall still do not meet safety standards, then by calculating using NPFA, individual time and speed can be obtained to exit the mall. Number of visitors Floor 3 1100 people

1. Calculation

   ➢ 3rd floor calculation:
average corridor area
= corridor total / corridor variable = 2073/25 = 83 m²

| No | Stairs        | Nearest (meters) | Farthest (meters) |
|----|---------------|------------------|-------------------|
| 1  | Emergency 1   | 16               | 95                |
| 2  | Emergency 2   | 52               | 91                |
| 3  | Emergency 3   | 5                | 91                |
| 4  | Emergency 4   | 18               | 86                |
| 5  | Escalator     | 24               | 99                |
| 6  | Ramp          | 13               | 90                |

2. Calculation of each ladder
*Table 2.1 : the distance of each ladder 3rd floor*
To find out the minimum and maximum travel time is Plus each distance and then divide with the number of variables:
- Nearest = 128 / 6 = 21.33 m
- Farthest = 552 / 6 = 92 m

3. Corridor density calculation
(D = p/m²) so 1100/83 = 13.25 p/m² so V = 0.18 m/s

4. Maximum and Minimum time
Distance is divide with the speed of the person moving so it can:
- Minimum Time :
  21.33 / 0.18 = 118 seconds
- Maximum Time :
  92/0.18 = 511 seconds

- 2nd floor calculation
2nd floor visitors 538 people
average corridor area
= 2396/27 = 89 m²

*Table 5. Distance and size based on each variable 2*

| No | Stairs        | Nearest (meters) | Farthest (meters) |
|----|---------------|------------------|-------------------|
| 1  | Emergency 1   | 7                | 88                |
| 2  | Emergency 2   | 6                | 80                |
| 3  | Emergency 3   | 5                | 72                |
| 4  | Emergency 4   | 3                | 108               |
| 5  | Escalator     | 5                | 59                |
| 6  | Ramp          | 10               | 88                |
5. Calculation of each ladder travel time is Plus each distance and then divide with the number of variables:
   - Nearest = 36 / 6 = 6 m
   - Farthest = 495 / 6 = 82.5 m

6. Corridor density calculation
   \(D = p/m^2\) so \(538/89 = 6\ p/m^2\) so \(V = 0.18\ m/s\)

7. Maximum and Minimum time
   Distance is divide with the speed of the person moving so it can:
   - Minimum Time:
     \(6 / 0.18 = 33.33\) seconds
   - Maximum Time:
     \(82/0.18 = 455.5\) seconds
   - 1st floor calculation
   1st floor visitors 120 people
   average corridor area
   \(= 328/10 = 32.8\ m^2\)

8. Calculation of each ladder travel time is Plus each distance and then divide with the number of variables:
   - Nearest = 119 / 4 = 29.75 m
   - Farthest = 303 / 4 = 76 m

9. Corridor density calculation
   \(D = p/m^2\) so \(120/32.8 = 3.65\ p/m^2\) so \(V = 0.18\ m/s\)

10. Maximum and minimum time
    Distance is divide with the speed of the person moving so it can:
    - Minimum time:
      \(29.75 / 0.18 = 165\) seconds
    - Maximum time:
      \(76/0.18 = 422.2\) seconds

\textbf{Table 6. Distance and size based on each variable 3}

| No | Stairs     | Nearest (meters) | Farthest (meters) |
|----|------------|------------------|-------------------|
| 1  | Emergency 1| 31               | 75                |
| 2  | Emergency 2| 56               | 115               |
| 3  | Escalator  | 6                | 33                |
| 4  | Ramp       | 26               | 80                |
5. Conclusion

From the above data it can be concluded that the Palladium Mall does not meet safety standards in terms of evacuation, because the average standard of people evacuating in buildings more than 4 stories is the fastest is 3 minutes and the longest is 60 minutes or 1 hour. If seen from the data above, it means that many evacuation victims will not come out of the mall. And if seen through the evacuation supporting elements there are still elements that do not meet the standards, if the elements are repaired then surely the victims who will evacuate will be faster.

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