The Application of *Floyd-Warshall* Algorithm in Solving Shortest Path Problem for Fire Evacuation System at High Rise Building (Case Study at eL Royale Hotel Bandung)

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Abstract

Wildfires can happen anytime and anywhere, for example in high rise bulding. In attempt to control the wildfires, evacuation routes is one of the most important aspects that each building developer should consider. Evacuation is an action of moving peoples from the danger zone or the area that affected by it to a safety zone with the intention of safety. When we're facing the wildfires situation in a building, the evacuation procedure focused on the best attempt to finding the shortest route in order to minimize time travel to get out from the building to the safety zone as quickly as possible. Evacuation planning in high rise building is totally different compared to evacuation planning in open ground. Main components such as rooms, lobbies, corridors, stairs, alleys, etc. can determine the evacuation planning to completely success or fail. This research will discuss about the application of *Floyd-Warshall* Algorithm in finding the solution of shortest path problem in wildfires evacuation system at eL Royale Hotel Bandung as object of this research.

Keywords : Wildfires, Evacuation, Shortest Path Problem, *Floyd-Warshall* Algorithm.

1. Introduction

Wildfire is an incident where unwanted fire occurs or fire that placed in a wrong area. It happens because of three reasons; by fuel, by oxygen, and by heat sources. Wildfire can happen in anywhere and anytime. For example, it can happen on hotel. Hotel is one example of high rise buildings that has a chance where wildfire can be happen. Quoted from *Decree of Indonesian Minister of Public Works* number 11/KPTS/2000, hotel is classified as building that has a chance of wildfire in section seven. Thus, hotel building does not have higher risk of wildfires. However, it doesn't mean that wildfire won't happen in the hotel building. So, the existence of fire protection equipment such as sprinkler, hydrant, smoke alarm, and fire extinguisher cannot be ruled out in every hotel.

Evacuation is an action of moving people from the affected area to the save zone which is far from the affected area. The purpose of it is to making sure that those people are saved. When wildfire happens in high rise building, the evacuation procedures are focused on searching the shortest route in order to minimize time travel from the danger area to the safer zone. Planning the evacuation in high rise building is different from planning evacuation from open ground. There are several aspects that we should pay attention to it. Those aspects are rooms, lobbies, stairs, corridors, and many more.

There are some algorithm that can be used to solving the shortest path problem, such as *Dijkstra* Algorithm, *Bellman-Ford* Algorithm, and *Floyd-Warshall* Algorithm. *Floyd-Warshall* Algorithm is one of the easiest algorithm to use because of it's simpleness to find the shortest route from every pair-points in the system (All-pairs Shortest Path) and it's very effective to find the optimal route.

This research will be discussed about the solution of the problem when finding the shortest route in case of wildfire incident in eL Royale Hotel Bandung. This problem solved by using Floyd-Warshall algorithm.

2. Description of Problem

To finding the solution from shortest path problem of fire evacuation system at eL Royale Hotel Bandung, we're using *Floyd-Warshall* Algorithm as our calculation method because of it's simpleness. Based from the data we've got from eL Royale Hotel Bandung, there are 224 guest rooms, which is spreaded from floor 2 until 15, 2 emergency exits, and 1 assembly point. Then, we draw a graph to represent guest rooms, corridors, stairs that everyone can access.

This system will include greater number of *nodes* and lines. To facilitate the calculation, we're gonna calculate the system from floor to floor, not the whole system. Based from the data, there are 255 *nodes* that builds the system, consists of 224 guest rooms, 28 emergency stair entries, 2 emergency stair exits, and 1 assembly point. As for the recap for the number of nodes in fire evacuation system in every floor can be seen in Table 2.1 below.

Table 1 Recap of *Nodes* from Each Floor in Fire Evacuation System at eL Royale Hotel Bandung

Floor	Guest Rooms	Entries	Exits	*Assembly Point*
1	0	0	2	1
2	16	2	0	0
3	16	2	0	0
4	16	2	0	0
5	16	2	0	0
6	16	2	0	0
7	16	2	0	0
8	16	2	0	0
9	16	2	0	0
10	16	2	0	0
11	16	2	0	0
12	16	2	0	0
13	16	2	0	0
14	16	2	0	0
15	16	2	0	0
Total	224	28	2	1

There are some assumptions we're using to this research, such as:

1) The method we're using is *Floyd-Warshall* Algorithm.
2) The calculation only applies in Tower C of eL Royale Hotel Bandung.
3) There are 224 guest rooms which is spreaded from floor 2 until floor 15.
4) There are 2 emergency stairs that can be accessed from every floors.
5) There are only one *assembly point* in this system, which is located in ground floor.
6) We're assumed that if one guest already choosing one emergency stairs from the floor he/she stayed, he/she can't moved to another stairs in next floor.
7) During the evacuation, lift is shutting off.
8) Individual parameters such as running speed, physical ability, gender, psychological condition, etc. has no effect into calculation.
9) We're using Borland C++ 5.02 version as calculating software to make the calculation easier.

3. Analysis of Calculation using *Floyd-Warshall* Algorithm

To finding the solution of shortest path problem in fire evacuation system at eL Royale Hotel Bandung using *Floyd-Warshall* Algorithm, we must start by forming a graph based on layout map we already got. For example, we using floor number 2 as a sample. Based on the layout, the graph of fire evacuation system at floor 2 eL Royale Hotel Bandung can be seen in Figure 3.1 below.

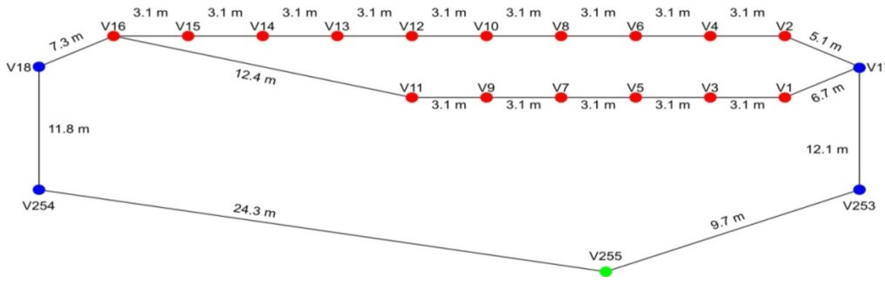

Figure 1 Graph of Floor 2 eL Royale Hotel Bandung

Based on that picture, there is some *nodes* that symbolized as a circles with three different colors. Red circles means hotel rooms, blue circles means access from/to fire emergency exits, and green circles means assembly point.

Using Figure 3.1, and some data that we got from Engineering Department, we obtained adjacency matrices W and Z as described below:

$W_0 =$

v_1	0	∞	3.1	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	6.7	∞	∞	∞	∞
v_2	∞	0	∞	3.1	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	5.1	∞	∞	∞	∞
v_3	3.1	∞	0	∞	3.1	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞
v_4	∞	3.1	∞	0	∞	3.1	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞
v_5	∞	∞	3.1	∞	0	∞	3.1	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞
v_6	∞	∞	∞	3.1	∞	0	∞	3.1	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞
v_7	∞	∞	∞	∞	3.1	∞	0	∞	3.1	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞
v_8	∞	∞	∞	∞	∞	3.1	∞	0	∞	3.1	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞
v_9	∞	∞	∞	∞	∞	∞	3.1	∞	0	∞	3.1	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞
v_{10}	∞	∞	∞	∞	∞	∞	∞	3.1	∞	0	∞	3.1	∞	∞	∞	∞	∞	∞	∞	∞	∞
v_{11}	∞	∞	∞	∞	∞	∞	∞	∞	3.1	∞	0	∞	∞	∞	∞	12.4	∞	∞	∞	∞	∞
v_{12}	∞	∞	∞	∞	∞	∞	∞	∞	∞	3.1	∞	0	3.1	∞	∞	∞	∞	∞	∞	∞	∞
v_{13}	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	3.1	0	3.1	∞	∞	∞	∞	∞	∞	∞
v_{14}	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	3.1	0	3.1	∞	∞	∞	∞	∞	∞
v_{15}	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	3.1	0	3.1	∞	∞	∞	∞	∞
v_{16}	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	12.4	∞	∞	∞	3.1	0	∞	7.3	∞	∞	∞
v_{17}	6.7	5.1	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	0	∞	12.1	∞	∞
v_{18}	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	7.3	∞	0	∞	11.8	∞
v_{253}	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	12.1	∞	0	∞	9.7
v_{254}	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	11.8	∞	0	24.3
v_{255}	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	9.7	24.3	0

$Z_0 =$

v_1	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	17	0	0	0	0
v_2	0	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0	17	0	0	0	0
v_3	1	0	0	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
v_4	0	2	0	0	0	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
v_5	0	0	3	0	0	0	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0
v_6	0	0	0	4	0	0	0	8	0	0	0	0	0	0	0	0	0	0	0	0	0
v_7	0	0	0	0	5	0	0	0	9	0	0	0	0	0	0	0	0	0	0	0	0
v_8	0	0	0	0	0	6	0	0	0	10	0	0	0	0	0	0	0	0	0	0	0
v_9	0	0	0	0	0	0	7	0	0	0	11	0	0	0	0	0	0	0	0	0	0
v_{10}	0	0	0	0	0	0	0	8	0	0	0	12	0	0	0	0	0	0	0	0	0
v_{11}	0	0	0	0	0	0	0	0	9	0	0	0	0	0	0	16	0	0	0	0	0
v_{12}	0	0	0	0	0	0	0	0	0	10	0	0	13	0	0	0	0	0	0	0	0
v_{13}	0	0	0	0	0	0	0	0	0	0	0	12	0	14	0	0	0	0	0	0	0
v_{14}	0	0	0	0	0	0	0	0	0	0	0	0	13	0	15	0	0	0	0	0	0
v_{15}	0	0	0	0	0	0	0	0	0	0	0	0	0	14	0	16	0	0	0	0	0
v_{16}	0	0	0	0	0	0	0	0	0	0	11	0	0	0	15	0	0	18	0	0	0
v_{17}	1	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	253	0	0
v_{18}	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	16	0	0	0	254	0
v_{253}	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	17	0	0	0	255
v_{254}	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	18	0	0	255
v_{255}	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	253	254	0

where $v_1, v_2, v_3, \ldots, v_{18}, v_{253}, v_{254}, v_{255}$ are nodes that forming fire evacuation system at floor 2.

Adjacency matrices W is used to find the shortest distance from every *node* pairs, while matrices Z is used to find the path from the shortest distance from every *node* pairs that we've already obtained in matrices W.

For example, W_0 is an adjacency matrices from a random directed and weighted graph, W^* is an new adjacency matrices with $w_{[i,j]}$ is a value from *edge* that connecting *node* i and *node* j. *Floyd-Warshall* Algorithm for finding the shortest path can be described below:

1) Pick $W = W_0$
2) For $k = 1,2,\ldots,n$
   For $i = 1,2,\ldots,n$
   For $j = 1,2,\ldots,n$, do :
   a. if $w_{[i,j]} > w_{[i,k]} + w_{[k,j]}$, then choose $w^*_{[i,j]} = w_{[i,k]} + w_{[k,j]}$.
   b. if $w_{[i,j]} \leq w_{[i,k]} + w_{[k,j]}$, then choose $w^*_{[i,j]} = w_{[i,j]}$.
3) Pick $W^* = W$ **(1)**

Floyd-Warshall Algorithm can be used for finding the shortest route only, but not describe its path. For finding the path that connected two random *nodes* using *Floyd-Warshall* Algorithm, we must added matrices Z that described as:

$$\text{Inizialiation } z_{[i,j]} = \begin{cases} j, \ if \ w_{[i,j]} \neq \infty \\ 0, \ if \ w_{[i,j]} = \infty \ or \ i = j \end{cases} \quad \textbf{(2)}$$

In every iteration, for every value changes of elements $w_{[i,j]}$ in adjacency matrices W, we must changed the value $z_{[i,j]}$ in matrices Z with $z_{[i,k]}$.
Based on that, updated version of *Floyd-Warshall* Algorithm **(1)** using matrices Z **(2)** is described below:

1) Pick $W = W_0$, $Z = Z_0$
2) For $k = 1,2,\ldots,n$
   For $i = 1,2,\ldots,n$
   For $j = 1,2,\ldots,n$, do :
   a. if $w_{[i,j]} > w_{[i,k]} + w_{[k,j]}$, then choose $w^*_{[i,j]} = w_{[i,k]} + w_{[k,j]}$ and $z^*_{[i,j]} = z_{[i,k]}$
   b. if $w_{[i,j]} \leq w_{[i,k]} + w_{[k,j]}$, then choose $w^*_{[i,j]} = w_{[i,j]}$ and $z^*_{[i,j]} = z_{[i,j]}$
3) Pick $W^* = W$, $Z^* = Z$ **(3)**

The method and solution of finding the shortest path problem using *Floyd-Warshall* Algorithm in floor 2 can be seen below.

Iteration *k = 1* :

For every elements in adjacency matrices W will be checked whether $w_{[i,j]} > w_{[i,k]} + w_{[k,j]}$, with :
*i = 1, 2, 3, ..., 18, 253, 254, 255***.**
j = 1, 2, 3, ..., 18, 253, 254, 255, and

k = 1, 2, 3, ..., 18, 253, 254, 255
If yes, then choose $w^*{}_{[i,j]} = w_{[i,k]} + w_{[k,j]}$ and $z^*{}_{[i,j]} = z_{[i,k]}$.

i = 1, j = 1
$w_{[1,1]} = 0$, meanwhile $w_{[1,1]} + w_{[1,1]} = 0 + 0 = 0$. So choose $w^*{}_{[1,1]} = 0$ and $z^*{}_{[1,1]} = 0$.

i = 1, j = 2
$w_{[1,2]} = \infty$, meanwhile $w_{[1,1]} + w_{[1,2]} = 0 + \infty = \infty$. So choose $w^*{}_{[1,2]} = \infty$ and $z^*{}_{[i,j]} = 0$.

i = 1, j = 3
$w_{[1,3]} = 3{,}1$, meanwhile $w_{[1,1]} + w_{[1,3]} = 0 + 3{,}1 = 3{,}1$. So choose $w^*{}_{[1,3]} = 3{,}1$ and $z^*{}_{[i,j]} = 3$.

Repeat those steps above until *i = 255* and *j = 255* so we can obtained an updated version of matrices W and Z as follows:

$W_1 =$

v_1	0	∞	3.1	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	6.7	∞	∞	∞	∞
v_2	∞	0	∞	3.1	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	5.1	∞	∞	∞	∞
v_3	3.1	∞	0	∞	3.1	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	9.8	∞	∞	∞	∞
v_4	∞	3.1	∞	0	∞	3.1	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞
v_5	∞	∞	3.1	∞	0	∞	3.1	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞
v_6	∞	∞	∞	3.1	∞	0	∞	3.1	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞
v_7	∞	∞	∞	∞	3.1	∞	0	∞	3.1	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞
v_8	∞	∞	∞	∞	∞	3.1	∞	0	∞	3.1	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞
v_9	∞	∞	∞	∞	∞	∞	3.1	∞	0	∞	3.1	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞
v_{10}	∞	∞	∞	∞	∞	∞	∞	3.1	∞	0	∞	3.1	∞	∞	∞	∞	∞	∞	∞	∞	∞
v_{11}	∞	∞	∞	∞	∞	∞	∞	∞	3.1	∞	0	∞	∞	∞	∞	12.4	∞	∞	∞	∞	∞
v_{12}	∞	∞	∞	∞	∞	∞	∞	∞	∞	3.1	∞	0	3.1	∞	∞	∞	∞	∞	∞	∞	∞
v_{13}	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	3.1	0	3.1	∞	∞	∞	∞	∞	∞	∞
v_{14}	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	3.1	0	3.1	∞	∞	∞	∞	∞	∞
v_{15}	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	3.1	0	3.1	∞	∞	∞	∞	∞
v_{16}	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	12.4	∞	∞	∞	3.1	0	∞	7.3	∞	∞	∞
v_{17}	6.7	5.1	9.8	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	0	∞	12.1	∞	∞
v_{18}	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	7.3	∞	0	∞	11.8	∞
v_{253}	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	12.1	∞	0	∞	9.7
v_{254}	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	11.8	∞	0	24.3
v_{255}	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	9.7	24.3	0

$Z_1 =$

v_1	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	17	0	0	0	0
v_2	0	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0	17	0	0	0	0
v_3	1	0	0	0	5	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
v_4	0	2	0	0	0	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
v_5	0	0	3	0	0	0	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0
v_6	0	0	0	4	0	0	0	8	0	0	0	0	0	0	0	0	0	0	0	0	0
v_7	0	0	0	0	5	0	0	0	9	0	0	0	0	0	0	0	0	0	0	0	0
v_8	0	0	0	0	0	6	0	0	0	10	0	0	0	0	0	0	0	0	0	0	0
v_9	0	0	0	0	0	0	7	0	0	0	11	0	0	0	0	0	0	0	0	0	0
v_{10}	0	0	0	0	0	0	0	8	0	0	0	12	0	0	0	0	0	0	0	0	0
v_{11}	0	0	0	0	0	0	0	0	9	0	0	0	0	0	0	16	0	0	0	0	0
v_{12}	0	0	0	0	0	0	0	0	0	10	0	0	13	0	0	0	0	0	0	0	0
v_{13}	0	0	0	0	0	0	0	0	0	0	0	12	0	14	0	0	0	0	0	0	0
v_{14}	0	0	0	0	0	0	0	0	0	0	0	0	13	0	15	0	0	0	0	0	0
v_{15}	0	0	0	0	0	0	0	0	0	0	0	0	0	14	0	16	0	0	0	0	0
v_{16}	0	0	0	0	0	0	0	0	0	0	11	0	0	0	15	0	0	18	0	0	0
v_{17}	1	2	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	253	0	0
v_{18}	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	16	0	0	0	254	0
v_{253}	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	17	0	0	0	255
v_{254}	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	18	0	0	255
v_{255}	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	253	254	0

Based on that matrices, we can see some values are changes, that is in $w_{[3,17]}$ and $w_{[17,3]}$. That means we've found the new shortest route from v_3 to v_{17} and vice versa, that is going through v_1. By that, the newest shortest route from v_3 to v_{17} are $v_3 \rightarrow v_1 \rightarrow v_{17}$.

Repeat those steps until $k = 255$, so we can obtained final adjacency matrices W* and Z* from the calculation using *Floyd-Warshall* Algorithm that shows the results of shortest distance of every *node* pairs and it's path.In full, the matrices W* and Z* can be seen below.

W* =

v_1	0	11.8	3.1	14.9	6.2	18	9.3	21.1	12.4	24.2	15.5	27.3	30.4	33.5	31	27.9	6.7	35.2	18.8	47	28.5
v_2	11.8	0	14.9	3.1	18	6.2	21.1	9.3	24.2	12.4	27.3	15.5	18.6	21.7	24.8	27.9	5.1	35.2	17.2	47	26.9
v_3	3.1	14.9	0	18	3.1	21.1	6.2	24.2	9.3	27.3	12.4	30.4	33.5	31	27.9	24.8	9.8	32.1	21.9	43.9	31.6
v_4	14.9	3.1	18	0	21.1	3.1	24.2	6.2	27.3	9.3	30.4	12.4	15.5	18.6	21.7	24.8	8.2	32.1	20.3	43.9	30
v_5	6.2	18	3.1	21.1	0	24.2	3.1	27.3	6.2	30.4	9.3	33.5	31	27.9	24.8	21.7	12.9	29	25	40.8	34.7
v_6	18	6.2	21.1	3.1	24.2	0	27.3	3.1	30.4	6.2	33.5	9.3	12.4	15.5	18.6	21.7	11.3	29	23.4	40.8	33.1
v_7	9.3	21.1	6.2	24.2	3.1	27.3	0	30.4	3.1	33.5	6.2	31	27.9	24.8	21.7	18.6	16	25.9	28.1	37.7	37.8
v_8	21.1	9.3	24.2	6.2	27.3	3.1	30.4	0	33.5	3.1	31	6.2	9.3	12.4	15.5	18.6	14.4	25.9	26.5	37.7	36.2
v_9	12.4	24.2	9.3	27.3	6.2	30.4	3.1	33.5	0	31	3.1	27.9	24.8	21.7	18.6	15.5	19.1	22.8	31.2	34.6	40.9
v_{10}	24.2	12.4	27.3	9.3	30.4	6.2	33.5	3.1	31	0	27.9	3.1	6.2	9.3	12.4	15.5	17.5	22.8	29.6	34.6	39.3
v_{11}	15.5	27.3	12.4	30.4	9.3	33.5	6.2	31	3.1	27.9	0	24.8	21.7	18.6	15.5	12.4	22.2	19.7	34.3	31.5	44
v_{12}	27.3	15.5	30.4	12.4	33.5	9.3	31	6.2	27.9	3.1	24.8	0	3.1	6.2	9.3	12.4	20.6	19.7	32.7	31.5	42.4
v_{13}	30.4	18.6	33.5	15.5	31	12.4	27.9	9.3	24.8	6.2	21.7	3.1	0	3.1	6.2	9.3	23.7	16.6	35.8	28.4	45.5
v_{14}	33.5	21.7	31	18.6	27.9	15.5	24.8	12.4	21.7	9.3	18.6	6.2	3.1	0	3.1	6.2	26.8	13.5	38.9	25.3	48.6
v_{15}	31	24.8	27.9	21.7	24.8	18.6	21.7	15.5	18.6	12.4	15.5	9.3	6.2	3.1	0	3.1	29.9	10.4	42	22.2	46.5
v_{16}	27.9	27.9	24.8	24.8	21.7	21.7	18.6	18.6	15.5	15.5	12.4	12.4	9.3	6.2	3.1	0	33	7.3	45.1	19.1	43.4
v_{17}	6.7	5.1	9.8	8.2	12.9	11.3	16	14.4	19.1	17.5	22.2	20.6	23.7	26.8	29.9	33	0	40.3	12.1	46.1	21.8
v_{18}	35.2	35.2	32.1	32.1	29	29	25.9	25.9	22.8	22.8	19.7	19.7	16.6	13.5	10.4	7.3	40.3	0	45.8	11.8	36.1
v_{253}	18.8	17.2	21.9	20.3	25	23.4	28.1	26.5	31.2	29.6	34.3	32.7	35.8	38.9	42	45.1	12.1	45.8	0	34	9.7
v_{254}	47	47	43.9	43.9	40.8	40.8	37.7	37.7	34.6	34.6	31.5	31.5	28.4	25.3	22.2	19.1	46.1	11.8	34	0	24.3
v_{255}	28.5	26.9	31.6	30	34.7	33.1	37.8	36.2	40.9	39.3	44	42.4	45.5	48.6	46.5	43.4	21.8	36.1	9.7	24.3	0

Z* =

v_1	0	17	3	17	3	17	3	17	3	17	3	17	17	17	3	3	17	3	17	3	17
v_2	17	0	17	4	17	4	17	4	17	4	17	4	4	4	4	4	17	4	17	4	17
v_3	1	1	0	1	5	1	5	1	5	1	5	1	1	5	5	5	1	5	1	5	1
v_4	2	2	2	0	2	6	2	6	2	6	2	6	6	6	6	6	2	6	2	6	2
v_5	3	3	3	3	0	3	7	3	7	3	7	3	7	7	7	7	3	7	3	7	3
v_6	4	4	4	4	4	0	4	8	4	8	4	8	8	8	8	8	4	8	4	8	4
v_7	5	5	5	5	5	5	0	5	9	5	9	9	9	9	9	9	5	9	5	9	5
v_8	6	6	6	6	6	6	6	0	6	10	10	10	10	10	10	10	6	10	6	10	6
v_9	7	7	7	7	7	7	7	7	0	11	11	11	11	11	11	11	7	11	7	11	7
v_{10}	8	8	8	8	8	8	8	8	12	0	12	12	12	12	12	12	8	12	8	12	8
v_{11}	9	9	9	9	9	9	9	16	9	16	0	16	16	16	16	16	9	16	9	16	9
v_{12}	10	10	10	10	10	10	13	10	13	10	13	0	13	13	13	13	10	13	10	13	10
v_{13}	12	12	12	12	14	12	14	12	14	12	14	12	0	14	14	14	12	14	12	14	12
v_{14}	13	13	15	13	15	13	15	13	15	13	15	13	13	0	15	15	13	15	13	15	13
v_{15}	16	14	16	14	16	14	16	14	16	14	16	14	14	14	0	16	14	16	14	16	16
v_{16}	11	15	11	15	11	15	11	15	11	15	11	15	15	15	15	0	15	18	15	18	18
v_{17}	1	2	1	2	1	2	1	2	1	2	1	2	2	2	2	2	0	2	253	2	253
v_{18}	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	0	254	254	254
v_{253}	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17	255	0	255	255
v_{254}	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	255	18	255	0	255
v_{255}	253	253	253	253	253	253	253	253	253	253	253	253	253	253	254	254	253	254	253	254	0

Based on matrices W* dan Z* above, we obtained the shortest distance from every rooms in floor 2 into assembly point with it's path. For example, if we are in the room number 240 (v_1) and we must going into assembly point (v_{255}), the shortest distance from room 240 into assembly point is 28,5 meters. Meanwhile, the route we must follow are :

$$z^{255}{}_{(1,255)} = 17$$
$$z^{255}{}_{(17,255)} = 253$$
$$z^{255}{}_{(253,255)} = 255$$

That means, the route we must follow are : $v_1 \rightarrow v_{17} \rightarrow v_{253} \rightarrow v_{255}$.

By using the calculation above, we obtained the solution of finding the shortest path problem in fire evacuation system at floor 2 eL Royale Bandung as described in Figure 3.2 below.

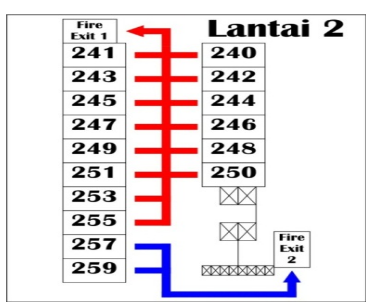

Figure 2 Fire Evacuation System Based on Solution of Shortest Path Problem at Floor 2 eL Royale Hotel Bandung

Based on picture above, we can conclude that for every guests that stay in rooms number 240 until 255, they must use fire exit number 1 or red tracks, meanwhile guests in rooms number 257 and 259 must use fire exit number 2 or blue tracks, in case of wildfire happens.

Using the same method, we can also find the solution of shortest path problem in fire evacuation system at floor 3 until floor 15. The fire evacuation system based on the shortest route for floor 3 until floor 15 can be seen in Figure 3.3 below.

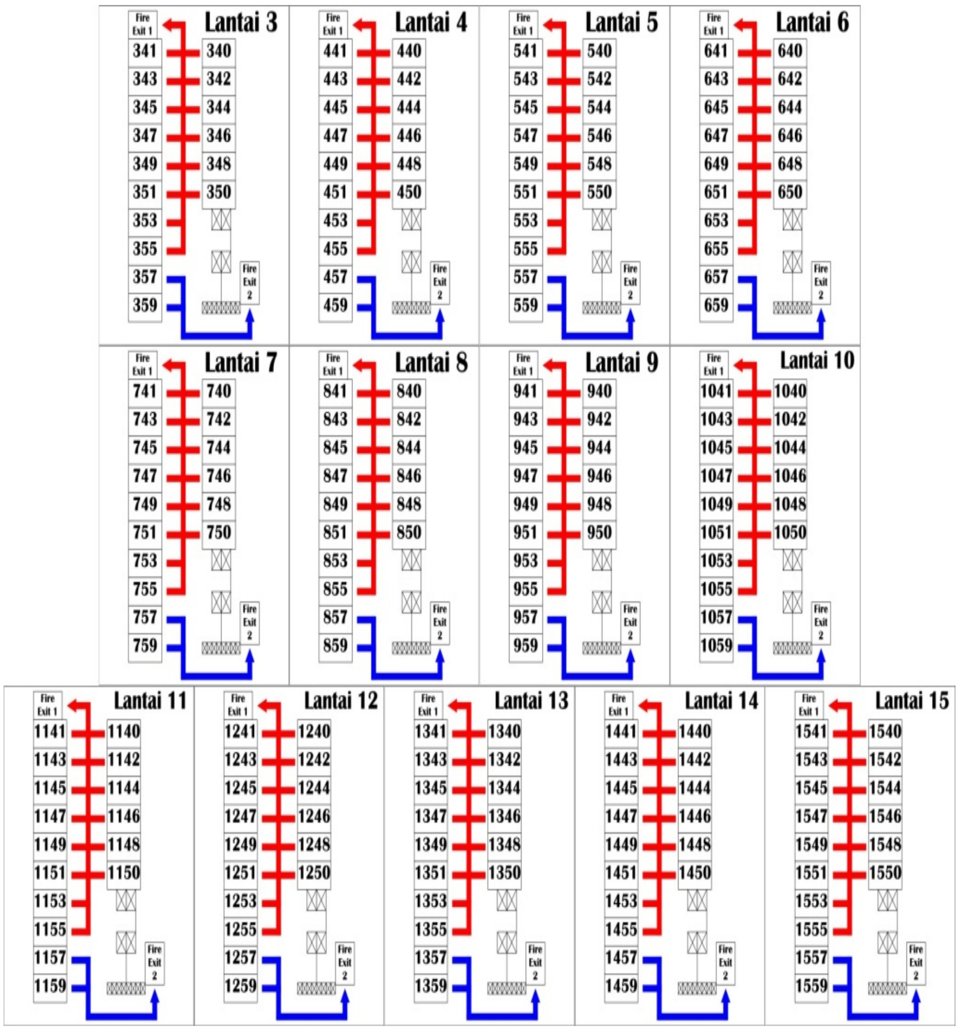

Figure 3 Fire Evacuation System Based on Solutions of Finding Shortest Path Problem at Floor 3-15 eL Royale Hotel Bandung

4. Results Analysis

Based from the calculation results from section 3, we've got the solution of shortest path problem in fire evacuation system at every floor from eL Royale Hotel Bandung using *Floyd-Warshall* Algorithm. As for the summary of emergency stairs choice of every rooms in eL Royale Hotel Bandung based on calculation using *Floyd-Warshall* Algorithm can be seen in Table 2 below.

Table 2 summary of emergency stairs choice of every rooms in eL Royale Hotel Bandung based on calculation using *Floyd-Warshall* Algorithm

Floor	Guest Rooms that must used Emergency Stair 1 (Red)	Guest Rooms that must used Emergency Stair 2 (Blue)
2	240, 241, 242, 243, 244, 245, 246, 247, 248, 249, 250, 251, 253, 255	257, 259
3	340, 341, 342, 343, 344, 345, 346, 347, 348, 349, 350, 351, 353, 355	357, 359
4	440, 441, 442, 443, 444, 445, 446, 447, 448, 449, 450, 451, 453, 455	457, 459
5	540, 541, 542, 543, 544, 545, 546, 547, 548, 549, 550, 551, 553, 555	557, 559
6	640, 641, 642, 643, 644, 645, 646, 647, 648, 649, 650, 651, 653, 655	657, 659
7	740, 741, 742, 743, 744, 745, 746, 747, 748, 749, 750, 751, 753, 755	757, 759
8	840, 841, 842, 843, 844, 845, 846, 847, 848, 849, 850, 851, 853, 855	857, 859
9	940, 941, 942, 943, 944, 945, 946, 947, 948, 949, 950, 951, 953, 955	957, 959
10	1040, 1041, 1042, 1043, 1044, 1045, 1046, 1047, 1048, 1049, 1050, 1051, 1053, 1055	1057, 1059
11	1140, 1141, 1142, 1143, 1144, 1145, 1146, 1147, 1148, 1149, 1150, 1151, 1153, 1155	1157, 1159
12	1240, 1241, 1242, 1243, 1244, 1245, 1246, 1247, 1248, 1249, 1250, 1251, 1253, 1255	1257, 1259
13	1340, 1341, 1342, 1343, 1344, 1345, 1346, 1347, 1348, 1349, 1350, 1351, 1353, 1355	1357, 1359
14	1440, 1441, 1442, 1443, 1444, 1445, 1446, 1447, 1448, 1449, 1450, 1451, 1453, 1455	1457, 1459
15	1540, 1541, 1542, 1543, 1544, 1545, 1546, 1547, 1548, 1549, 1550, 1551, 1553, 1555	1557, 1559
Total	196	28

Based from that table above, we can conclude that guests that stayed at rooms number 240 – 255, 340 – 355, 440 – 455, 540 – 555, 640 – 655, 740 – 755, 840 – 855, 940 – 955, 1040 – 1055, 1140 – 1155, 1240 – 1255, 1340 – 1355, 1440 – 1455, and 1540 – 1555 must using emergency stair 1 (red), while guests that stayed at rooms number 257, 259, 357, 359, 457, 459, 557, 559, 657, 659, 757, 759, 857, 859, 957, 959, 1057, 1059, 1157, 1159, 1257, 1259, 1357, 1359, 1457, 1459, 1557, and 1559 must using emergency stairs 2 (blue).

5. Conclusion

Based from the summary in section 4, we can draw several conclusions, that is:

a. *Floyd-Warshall* Algorithm can be used to find the solution of shortest path problem in fire evacuation system at eL Royale Hotel Bandung with the final results of calculation are a system of fire evacuation with the shortest route possible from every rooms there into assembly point.
b. The evacuation route that obtained from the calculation using *Floyd-Warshall* Algorithm in order to minimize the route distance are, from rooms number 240 – 255, 340 – 355, 440 – 455, 540 – 555, 640 – 655, 740 – 755, 840 – 855, 940 – 955, 1040 – 1055, 1140 – 1155, 1240 – 1255, 1340 – 1355, 1440 – 1455, and 1540 – 1555 must using emergency stair 1 (red), while rooms number 257, 259, 357, 359,

457, 459, 557, 559, 657, 659, 757, 759, 857, 859, 957, 959, 1057, 1059, 1157, 1159, 1257, 1259, 1357, 1359, 1457, 1459, 1557, and 1559 must using emergency stairs 2 (blue)..

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