ISSN: 2710-0588

Emergency Escape Route Design and Application

Yanmin Man
School of Electrical Engineering, Computing and Mathematical Sciences, Curtin University, Perth, Australia

Abstract

This paper uses k-means clustering algorithm, single objective optimization model and multisource multi-sink problem shortest path algorithm to obtain the optimal path algorithm for emergency evacuation and the shortest time model.Firstly, a code of conduct for the division of terrorist attacks has been established. The number of casualties in various incidents and the scope of destructive power to public areas are counted. A three-dimensional cluster core is selected. All terrorist at- tacks are classified into three levels: level 1-3 by the k-means clustering algorithm, and the degree of harm is gradually increasing.Secondly, the optimal path from each venue to the stairway is calculated. The re- lationship between the speed of flow and the number of evacuees is given in the case of three situations. The multi-source multi-sink problem is transformed into a single- source shortest path problem by adding a virtual node to all venues on the second floor of the Louvre, and the Dijkstra algorithm is called once to obtain the optimal path from the venue to all stairs.The Final step is to establish an emergency evacuation optimization model with the minimum evacuation time as the objective function. The overall evacuation time is divided into the personnel response time, the horizontal road walking time, the time down the stairs, and the waiting time when congestion occurs. the open number of emergency exits can be judging by different levels of terrorist events, and the optimal evacuation path and the shortest time for different emergency events are given. At the same time, we also analyzed the changing trend of velocity in different cases, which can be adjusted according to the actual conditions.

Keywords

The Shortest-path Optimization; k-means Clustering Algorithm; Dijkstra Algorithm.

1. Introduction

1.1. Introduction to Louvre

Located on the north bank of the Seine river in central Paris, the Louvre museum ranks first among the world's four major museums. Founded in 1204, it was once the palace of France, where 50 French Kings and queens lived.The Louvre Museum of Art was officially opened to the public as a museum. The Louvre has become one of the world famous art halls and one of the biggest art treasures.

1.2. Description of Problem

In recent years, the terrorist attacks in France have become more and more fre- quent. and the Louvre in Paris, France, is one of the largest and most visited art muse- ums in the world (with more than 8. 1 million visitors in 2017). The number of tourists is not quantitative. The Louvre has five floors, two of which are underground.

The pyramid entrance is the main and most commonly used public entrance to the Louvre, while the other three are reserved for the Louvre member groups and individu- als at the: Passage Richelieu entrance and the Portes Des Lions entrance.The total exit point is known only to emergency personnel and officials, but there are security risks at these intersections. Due to

ISSN: 2710-0588

the number of uses of the Louvre exit and the level of terror- ist attacks. Therefore, in an emergency In this case, the evacuation plan for the Louvre will become more challenging. Please design an emergency evacuation plan that can be used in a variety of situations.

1.3. Problem Background

This problem can be seen as the optimization of the optimal evacuation plan, and this problem contains many factors, such as the type of terrorist attack, the shortest distance, and the shortest time. First, we can rank terrorist attacks in order to determine the number of exports that need to be opened for the incident.

Considering the distance and time passed by each adjacent area and the shortest time from each area to the evacuation port, the optimal test and the closed-loop method are used to adjust the plan to obtain the final evacuation plan.

1.4. Our Works

We start to solve the problem by understanding the tasks we are going to achieve. Our ultimate goal is to give a corresponding evacuation plan under different types of terrorist attacks.

First of all, we have conducted statistics on the number of casualties and other as- pects of terrorist attacks in recent years in order to obtain the level of terrorist attacks. We use the k-means clustering final cluster center method. Divide all terrorist attacks into three levels.

Secondly, calculating the evacuation path of each stadium to the stairway, first cal- culating the shortest route of each stadium, this paper provides a new idea, that is, by adding a virtual node to connect all the source points, the multi-source multi-sink prob- lem will be transformed into a single-source shortest path problem. The Dijkstra algo- rithm can be called only once to obtain the shortest path from the source point to all the meeting points, and then establish the shortest time optimization model and give the withdrawal plan under different terrorist events.

2. General Assumptions

In order to ensure that our models are valid and reasonable, and to simplify the problem, we make a number of assumptions of the problem. Before going into detail about our approach, we list those assumptions as follows:

(1)Evacuation by stairs only;

(2)No obstacles in the aisle and on the stairs;

(3)Ignore the fall phenomenon;

(4)If there is a stagnant stairway, it will be processed according to the queue status.

3. Variables

Table 1. Variables

Variables	Descriptions
M	Total number of Crowd density
S	Horizontal projection area of a single person
H	Pedestrian width
L	Pedestrian length
G	Number of partners
p	Correction coefficient for downstairs
g	Standard deviation of pedestrian speede
$u1, u2$	correction factor

ISSN: 2710-0588

Nj	Number of persons in group j
d	Body thickness
Lj	The total distance from group j to the stairs
Ls	Inclination length of stairs
B	Effective width of floor platform and intermediate platform
b	Width of stair
tk	Personnel waiting time in floor k
λ	Distance of the farthest person passing through stair
T	Total evacuation time
t_0	The reaction time

4. Terrorist Attack Level

In this section, the first part of the website to give the news about the terrorist at- tacks data, based on the available data comprehensive analysis of the use of different weapons casualty estimates, search for website data, Based on past experience, the im- pact on the evacuation of the museum area when the terrorist incident occurred in var- ious areas of the museum is judged. The museum area is divided into three major areas. The details are as follows:

Table 2. Predicting the number of casualties

Weapon	Kills and Injured	Areas	Influence
Non-firearm explosives	3	Entrance	10
Gun and Wound	10	Staircase	8
Car	80	Exhibition Area	4

Then use the k-means clustering algorithm to cluster the samples, divide all terror- ist attacks into three categories, respectively, indicating the different degree of harm ofthe sample events, and divide them into one to four levels from high to low. The classi- fication method is as follows:

Table 3. Casualty estimate and impact level combination

Type	Data
Gun and Wound; Staircase	(10, 8)
Non-firearm explosives;Car;Entrance	(83,10)
Non-firearm explosives; Gun and Wound; Exhibition Area	(93,4)

Then use the k-means clustering algorithm to cluster the samples, divide all ter- rorist attacks into three categories, respectively, indicating the different degree of harm of the sample events, and divide them into one to three levels from high to low. The classification method is as follows:

(1)Select three focal points and bring in the above xi data points. Select the Euro- pean distance d as a measure of similarity between data samples. The European dis- tance calculation formula is as follows:

$$d\ (xi\ ,\ kj) = (xi - kj)2\ ;\ i = 1, \ldots , n;\ j = 1, 2, 3. \tag{1}$$

ISSN: 2710-0588

(2)Determine whether xi belongs to the Kj, (j = 1, 2, 3)class with the shortest dis- tance between the data point xi and the dot core Kj;

Step 1: Assign the values of all samples to 3 non-empty clusters based on the short- est distance;

Step 2: Calculate the average value of each cluster and use the average value to represent the corresponding cluster for updating;

Step 3: Repeat steps 1, 2 until kj(j = 1, 2, 3) is always within the error range to com- plete the classification;

Step 4: Calculate the sum of the distance between each object and the center of each cluster is less than or equal to 15, i.e. $d(xi, kj) \leq 15$; If it is less than 15, the result of this clustering is output; Otherwise, jump out of this bad iteration and return(1), or when the number of times is greater than 200, the maximum replacement distance is recalculated; Select xi that satisfies $d(xi, kj) \leq 15$, then xi belongs to the Kj class, Where j = 1, 2, 3.

After clustering, three levels of each type of terrorist incident are obtained. For de- tails, see the attached page.

Table 4. Hazard impact table

Type	Distance interval	Hazard level
Gun and Wound Staircase	[0.00000000e+00 1.25652060e-02]	3
Non-firearm-explosives Car Entrance	[1.00000000e+00 2.92900765e-02]	2
Non-firearm-explosives Gun and Wound Car Exhibition Area	[2.00000000e+00 5.21601728e-03]	1
......	......	......

At this point, all 21 types of terrorist emergencies were classified according to the degree of harm, of which the degree of harm was 1, 2, and 3 from high to low.

The title gives that no matter what kind of terrorist attack takes place, all personnel must be evacuated. Therefore, when a terrorist attack occurs, we only need to deter- mine whether we need to open the alternate exit to the Passage Richelieutrance, the Carrousel du Louvre exit, and the Portes Des Leons office.

5. Evacuation Speed Analysis

The speed of evacuation refers to the speed of walking of the crowd, mainly based on the speed of the front row of the flow of people, and the introduction of Predtechen- skii and Milinskii in this section on normal flow, comfortable flow, and emergency flow. The study of the speed of walking under the density of three types of people. Thus, the evacuation speed of different road conditions are analyzed in order to calculate the final evacuation time.

5.1. Analysis of Basic Behavior of Evacuated Personnel

In this section, the basic behavior of evacuees is studied and analyzed. According to the data of visitors to the Louvre, many visitors come to visit the Louvre with their families or tour groups. In case of an emergency, there is a high probability that they will go with each other.

As shown in the figure, Partner behavior will have a certain impact on the speed of walking. Under the same conditions, the speed of walking will decrease as the number of people in partnership increases. When pedestrians walk together, The role of the prime has been weakened and the speed needs to be coordinated with each other.

ISSN: 2710-0588

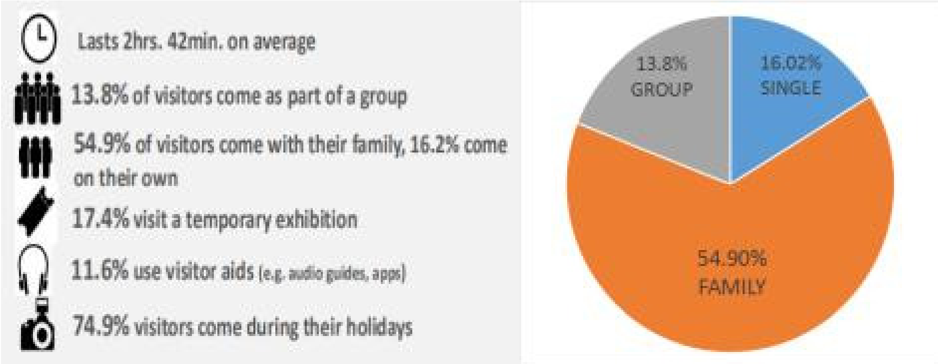

Figure 1. Their visit

5.2. Evacuation Speed

In this paper, we refer to the study of the speed of walking under normal flow, com- fortable flow, and emergency flow of the Predtechenskii and Milinskii, and give the rela- tionship between the speed of walking and the density of flow along the stairs and down the stairs, and propose the speed increase coefficient for the emergency flow.

(1)Moving speed on a horizontal channel

On the horizontal channel, the evacuation speed of the crowd is a function of the population density. M represent the population density and have the following speed formula.

$$V1 = 1.867M4 - 6.333M3 + 7.233M2 - 3.617M + 0.95, \tag{2}$$

In the formula, M = NS/HL, N is the total number of people in the walking flow, S is the horizontal projection area of a single person (m2), and H is the width (m), L is the length of the stream of people(m), and the application range of the above formula is

$0 < M \leq 0.92$.

(2)Speed of movement down the stairs

$$V2 = pV1\ ,\ p = 0.775 + 0.44e - 0.39M \times \sin(5.16M - 0.224), \tag{3}$$

p is the correction factor when going down the stairs.

(3)Speed through the door

$$V3 = V1[1.17 + 0.13\sin(6.03M - 0.12)], \tag{4}$$

In the formula, M = NS/HL, N is the total number of people in the walking flow, S is the horizontal projection area of a single person (m2), and H is the width (m), L is the length of the stream of people (m), and the application range of the above formula is

$0 < M \leq 0.92$.

(4)Speed of going forward

Here, the standard deviation of the pace of the companions is used to reflect this situation. The visit data of the attractions are investigated and the statistical changes in the speed of pedestrians in different pairs are obtained:

The table shows changes in the average speed and standard deviation of pedestri- ans walking together. It can be seen that with the increase in the number of compan- ions, the standard deviation of walking speed and speed shows a downward trend.

ISSN: 2710-0588

Table 5. Statistical value of pedestrian speed with different number of partners

Companion situation	Data(People)	Speed average(m/s)
Alone	76	1.2909
Two	100	1.1187
More Than two	31	1.0763

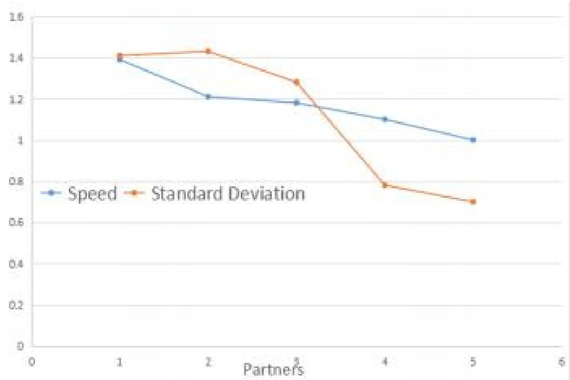

Figure 2. Impact on speed and standard deviation by the number of partners.

Pedestrians will communicate with each other when they are together. If there are too many partners, they will spontaneously carry out more detailed partnerships again, leading to the decomposition of large groups of difficulties and eventually forming two or more small knot groups.

Assuming that the number of companions is G, the corresponding speed is v4 , and the standard deviation is a, a logarithmic model can be constructed, and the parameter value can be determined by regression analysis,

$$v4 = v1\,(-0.1497 \ln G + 1.0095),\ g = -0.0516 \ln G + 0.1757. \tag{5}$$

(5) Congested section moving speed

In emergency evacuation, people usually have great psychological pressure, caus- ing changes in the speed of escape. At this point, the normal flow speed needs to be corrected with an increase factor of u1 . That is, the emergency pop speed is V_1', and $V_2'$is:

$$V_1' = u1\ v1\ , V_2' = u2\ v2\ , \tag{6}$$

Congestion for horizontal channels and open doors, u1 = 1.49 - 0.36M; Congested when going downstairs, u2 = 1.21M.

6. Model Establishment of Evacuation Plan

For an emergency evacuation, the shorter the evacuation time spent, the more suc- cessful the evacuation plan is. Therefore, the ultimate goal of the model establishment is to give the shortest evacuation path.

In this article, each venue is considered as a whole, that is, people in the same venue need to go to the same escape staircase in principle, and because the second floor of the underground has the largest exit, and the first basement has a direct passage to the basement. Therefore, it is only

ISSN: 2710-0588

necessary to calculate the evacuation time from the first floor and the second floor to the first floor.

6.1. Optimal Path

When there are multiple exits, the evacuation problem can be abstracted into a multi-source multi-sink problem based on the indoor network, that is, personnel from multiple venues(source points) need to quickly and safely reach multiple safe exits(points of exchange) in the shortest possible time. The following is a schematic diagram of the virtual node of the second floor map of the Louvre, where the circle is the number of the venue, and the square is the corre- sponding staircase entrance of the second floor, numbered 1-7 below:

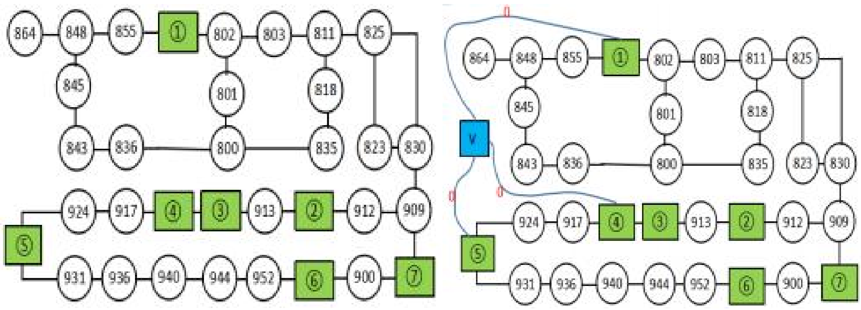

Figure 3. The Virtual Node is Added to the Original Road Network.

Add a virtual node to the multi-source multi-sink network and set the path length from the virtual node to the source point(exit) to 0. Then, using the virtual node as the s- tarting point, the shortest path analysis of the new road network is performed according to the Dijkstra algorithm.

First, the virtual node is added to the determined shortest path set N, and all other nodes are added to the undetermined path set U. At this time, the entire road network will expand outwards from the virtual node, and each meeting point(room) is deter- mined. The shortest path, To add this point to the set N. The specific algorithm steps are as follows:

Step 1: Enter the network source dot number first;

Step 2: Create an adjacency matrix to join the virtual node S, setting the path dis- tance from S to the source point to 0;

Step 3: Then add all nodes except virtual nodes to the undetermined shortest path set U;

Step 4: Determine whether the number of nodes in U is greater than 0, that is, whether there are nodes in the U set that have not yet determined the shortest path;

Step 5: When C is greater than 0, define min as the subscript of the first node in U;

Step 6: Determine whether the distance from S to U is less than the distance from S to U in the minute node. If the distance from S to U in the I node is less than the distance from S to U in the minute node, The value of min is changed to I. Otherwise, the min value will not change;

Step 7: Determine whether to compare the distance between all nodes in S to U, then the algorithm continues to run downwards, otherwise perform step 6 again;

Step 8: Remove the node subscript min from the U set and move into the deter- mined shortest path node set N;

Step 9: Compare the path distance of any node J in virtual node S to U(dis[j]) The path distance from S to the node subscript min(dis[min]) Path distance from node to node J with subscript min[min, J]) The size of the sum, if dis[j]>dis[min]+matrix[min, j] , then dis[j] The value is changed to dis[j] + matrix[min, j] ; Otherwise dis[j] The value remains unchanged;

ISSN: 2710-0588

Step 10: Return step 4 and continue the loop until the value of C is 0, that is, all nodes have found the shortest path.

Algorithm flow is shown below:

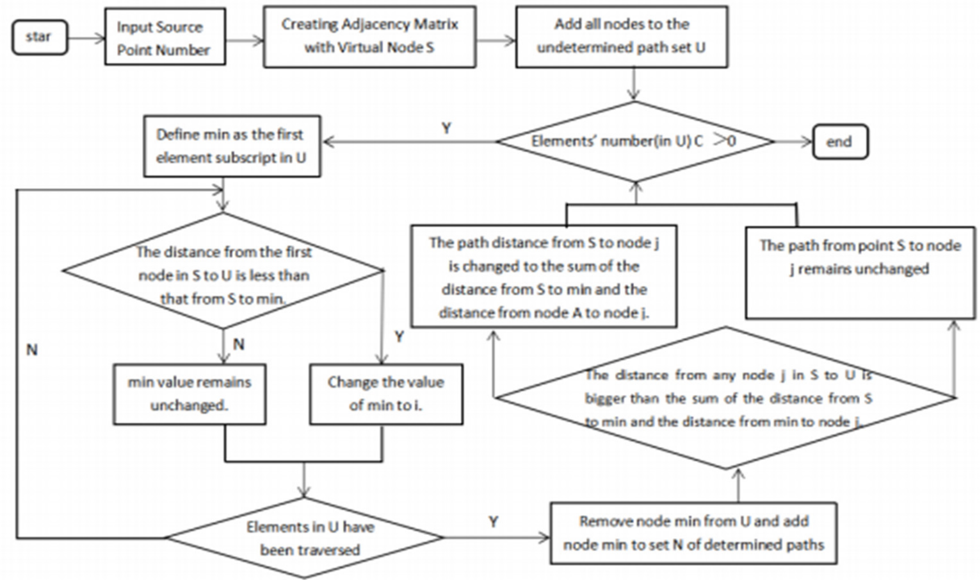

Figure 4. The Flow Chart of the Proposed Algorithm.

After Python software calculations, and combined with the idea of similar stairs evacuation numbers, we got the nearest staircase distribution table corresponding to the venues on the second floor of the Louvre as follows:

Table 6. The shortest path to the second floor of the Louvre stadium and stairs

Venue	Shortest stairs sort	Venue	Shortest stairs sort
800	O_1, O_7, O_6, O_2, O_5, O_4, O_3	801	O_1, O_7, O_6, O_2, O_5, O_4, O_3
802	O_1, O_7, O_6, O_2, O_5, O_4, O_3	803	O_1, O_7, O_6, O_2, O_5, O_4, O_3
811	O_1, O_7, O_6, O_2, O_5, O_4, O_3	818	O_7, O_6, O_1, O_2, O_5, O_4, O_3
823	O_7, O_6, O_1, O_2, O_5, O_4, O_3	825	O_7, O_6, O_1, O_2, O_5, O_4, O_3
830	O_7, O_6, O_2, O_1, O_5, O_4, O_3	835	O_7, O_6, O_1, O_2, O_5, O_4, O_3
836	O_1, O_7, O_6, O_2, O_5, O_4, O_3	843	O_1, O_7, O_6, O_2, O_5, O_4, O_3
845	O_1, O_7, O_6, O_2, O_5, O_4, O_3	848	O_1, O_7, O_6, O_2, O_5, O_4, O_3
855	O_1, O_7, O_6, O_2, O_5, O_4, O_3	865	O_1, O_7, O_6, O_2, O_5, O_4, O_3
900	O_6, O_7, O_2, O_5, O_1, O_4, O_3	902	O_7, O_6, O_2, O_5, O_1, O_4, O_3
909	O_7, O_6, O_2, O_1, O_5, O_4, O_3	912	O_2, O_7, O_6, O_1, O_5, O_4, O_3
913	O_2, O_7, O_6, O_1, O_5, O_4, O_3	917	O_4, O_3, O_2, O_5, O_4, O_1, O_3
924	O_5, O_4, O_3, O_2, O_6, O_7, O_1	931	O_5, O_4, O_3, O_2, O_6, O_7, O_1
936	O_5, O_4, O_3, O_2, O_6, O_7, O_1	940	O_5, O_6, O_7, O_4, O_3, O_2, O_1
944	O_6, O_7, O_5, O_2, O_4, O_3, O_1	952	O_6, O_7, O_2, O_5, O_1, O_4, O_3

6.2. Shortest Evacuation Time Model

Due to the particularity of multi-storey indoor buildings, this section mainly dis- cusses the K-floor evacuation time model, staircase evacuation model, queue waiting time model, and overall evacuation model.

6.3. K-layer Evacuation Time Model

According to the hazardous area site architecture, assuming that the distance be- tween people is D , due to congestion and detention conditions at the stairs, the evacu- ated people are divided into j groups, With such a large number of people and a body thickness of d, the total distance from the j group to the stairway entrance is Lj, and the total evacuation time(the last person leaves the floor) is:

$$t_j = \frac{L_j}{v_1} + \frac{(N_{j-1})D + dN_j}{v_2}. \tag{7}$$

However, due to the particularity of the evacuation site, in order to ensure the evac- uation safety and avoid accidents such as the fall of personnel, the evacuation model should be adopted as far as possible before the evacuees leave the museum. Therefore, if the two groups meet, the arrivals must wait. Therefore, the total evacuation time for the K-level personnel is:

$$T_K = \begin{cases} \frac{L_j}{v_1} + \frac{(N_j-1)D+dN_j}{v_2}, \\ \frac{(N_{j-1}-1)D+dN_(j-1)}{v_2} \leq \frac{(L_j-L_(j-1)}{v_1}, \\ \frac{L_j}{v_1} + \frac{(\sum_{j=1}^{m} N_1-1)D+d\sum_{j=1}^{m} N_1}{v_2}, \\ \frac{(N_{j-1}-1)D+dN_(j-1)}{v_2} > \frac{(L_j-L_(j-1)}{v_1}. \end{cases} \tag{8}$$

6.4. Stair Evacuation Time Model

The slope length of each floor is known to be Ls, the effective width of the floor platform and intermediate platform is B , and the width of the steps is b, The stairs evac- uation time between the target layer of n1 and the starting floor of n2 is:

$$T_{s,i} = \frac{\sum_{i=n_1}^{n_2} 2(L_s + B - b)}{v_2}, \tag{9}$$

6.5. Queue Waiting Time Model

There are two kinds of situations when the evacuees on the upper and lower levels meet: O1 (K-A) personnel first arrive at the stairs, and the K-level personnel need to wait for tK1; O2After the(K-A) personnel arrives at the stairs, the waiting time is tK2 . The formula for the two cases is expressed as follows:

$$\begin{aligned} &\frac{L_{j-1}}{v_1} \leq \frac{L_j}{v_1} + T_{s,i} \leq T_{K-A}, \\ &\frac{L_j}{v_1} + T_{s,i} < \frac{L_{j-1}}{v_1} < T_{K-A}, \end{aligned} \tag{10}$$

In order to ensure the evacuation safety, the arriving person must wait for the first arrival to complete the evacuation before beginning the evacuation. Thus, the waiting time for the two cases is as follows:

$$\begin{aligned} t_{K1} &= \frac{(\sum_{j=1}^{m} N_1 - 1)D + d\sum_{j=1}^{m} N_1}{v_2} + \frac{(L_j - L_(j-1)}{v_1} - T_{s,i}, \\ t_{K2} &= \frac{(\sum_{j=1}^{m} N_1 - 1)D + d\sum_{j=1}^{m} N_1}{v_2} - \frac{(L_j - L_(j-1)}{v_1} - T_{s,i}. \end{aligned} \tag{11}$$

6.6. Overall Evacuation Time Model

Taking into account the response time of t0 , the time when all evacuees leave the dangerous area is:

$$T = t_0 + T_K + T_{s,i} \tag{12}$$

If you consider reaching the ground as the evacuation destination, you need to in- crease the waiting time, the overall evacuation model is:

ISSN: 2710-0588

$$T' = \begin{cases} T + t_{K1}, \frac{(L_(j-1)}{v_1} \leq \frac{L_j}{v_1} + T_{s,i} \leq T_{K-A}, \\ T + t_{K2}, \frac{L_j}{v_1} + T_{s,i} < \frac{(L_(j-1)}{v_1} < T_{K-A}, \end{cases} \tag{13}$$

7. Solving The Optimal Evacuation Scheme

For the actual situation of the Louvre, in order to minimize the total evacuation time during the evacuation process, we only need to consider the shortest waiting time for the evacuation. The distance between the corresponding venues in the second floor of the Louvre is given below. Maps can be found in attached pages.

7.1. The Optimal Evacuation Scheme of Louvre

The red area represents the corresponding venue, and the yellow area represents the second floor staircase, numbered j (j = 1, ..., 7)stairs, Ni j is the number of people who pass through the i floor and the j stairs. λ is the distance traveled by the furthest person through the j stairway, then the time required for the Ni j individual to pass through the j stairway is:

$$t_i = \frac{\lambda}{v_1} + \frac{(N_{ij}-1)D + dN_{ij}}{v_2} + C, \text{C is a constant.} \tag{14}$$

For the i layer, there is a total of j (j = 1, ..., 7)stairs, the queue time for the i floor is max ti, and the optimization model for the overall evacuation is established with the shortest total waiting time,

$$\begin{aligned} &T_i = \min\{\max t_i\}, \\ &s.t. \begin{cases} \sum_{j=1}^{m} N_{ij} = N, \\ t_i = \frac{\lambda}{v_1} + \frac{(N_{ij}-1)D + dNij}{v_2} + C, \\ D, d, C, \lambda > 0, \end{cases} \end{aligned} \tag{15}$$

(1) Parameter settingD = 0.5m čňv1 = 1.2m/s, v2 = 1m/s; Substituting data into the model also uses lingo to solve;

t1 = 485. 15, t2 = 482, t3 = 483.05, t4 = 484. 1, t5 = 485. 15, t6 = 485. 15, t7 = 485. 15,
N1 = 785, N2 = 761, N3 = 772, N4 = 763, N5 = 784, N6 = 681, N7 = 746,

(2) According to the average number of people in each venue, the number of venues to pass through each staircase is calculated as four;

(3) Combining the optimal path of 6. 1, the shortest time is T = 485.15s, and the e- vacuation route of the second floor of the Louvre is as follows:

After the second floor of the staff goes down to the first floor, the next evacuation will be carried out directly at the corresponding stairway. Similarly, the evacuation route of the first floor can be calculated. Eventually, all venue personnel will leave from the 0 floor.

At this time, due to the different risk levels of terrorist incidents, the number of open emergency exports is also different. According to the classification of terrorist incidents calculated in Chapter 4, the number of emergency exports can be divided into two situations: level three event, four ordinary exits can be opened; Level two event, four ordinary exits and eight emergency doors; four ordinary exits and all emergency doors.

Table 7. Louvre's second floor evacuation route

Venue	Path	Venue	Path
836	836—800—O_6	843	843—855—O_1—802—O_5
845	845—855—O_1—802—O_7	848	848—855—O_1—802—O_7
855	855—O_1	864	864—848—O_7
900	900—912—O_2	902	902—O_3
909	909—902—O_3	912	912—909—902—O_4
913	913—O_2—912—909—902—O_4	917	917—O_4
924	924—917—O_4	931	931—O_3
936	936—931—O_5	940	940—936—931—O_5
944	944—940—936—931—O_5	801	801—802—O_1
802	802—O_1	803	803—802—O_1
835	835—830—O_2	952	952—6—900—O_2
825	825—830—909—912—O_2	800	800—830—909—902—O_7
811	811—825—830—909—902—O_7—900—O_6	818	818—835—830—909—902—O_7—900—O_6
823	823—825—830—909—902—O_7—900—O_6	830	830—944—940—936—931—O_5—924—917—O_3

Since the evacuation methods for the first and second floors are the same, as shown in the figure below, when the evacuees on the second floor of the first floor reach the 0 floor, they are all at the yellow point in the figure and divide the 0 floor into 13 areas. Give all the emergency doors.

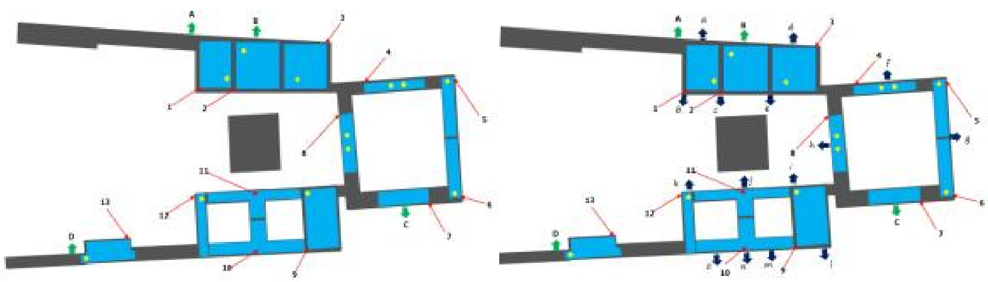

Figure 5. Louvre's regular export and emergency exit distribution map.

Level 3 event

only open four ordinary exits. After the Dijkstra algorithm starting from the virtual node, the shortest path analysis of the new road network shows that the shortest time is 485.15s, and the evacuation route is:

Table 8. Evacuation path for level 3 events

Venue	Path	Venue	Path	Venue	Path
1	1–A	2	2–A	3	3–B
4	4–B	5	5–C	6	6–C
7	7–C	8	8–B	9	9–C
10	10–D	11	11–D	12	12–D
13	13–D				

ISSN: 2710-0588

Level 2 event

Under the premise of opening ordinary four exits, it is still necessary to open eight emergency secret doors, a total of 12 emergency exits, the shortest time is 320.78s. The evacuation route at this time is:

Table 9. Evacuation path for level 2 events

Venue	Path	Venue	Path	Venue	Path
1	1-*A*	2	2-*B*	3	3-*d*
4	4-*f*	5	5-*g*	6	6-*g*
7	7-*C*	8	8-*h*	9	9-*i*
10	10-*n*	11	11-*j*	12	12-*k*
13	13-*D*				

Level 1 event

Under the premise of opening ordinary four exits, all 15 emergency secret doors still need to be opened. At this time, the 0-story re-block is re-divided. See the annex for the specific block simulation map, a total of 19 emergency exits. The shortest time is 240.36s. The evacuation route is as follows:

Table 10. Evacuation path for level 1 events

Venue	Path	Venue	Path	Venue	Path	Venue	Path
1(1)	1(1)-*A*	1(2)	1(2)-*b*	1(3)	1(3)-*c*	2(1)	2(1)-*B*
2(2)	2(2)-*a*	2(3)	2(3)-*c*	2(4)	2(4)-*e*	3(1)	3(1)-*d*
3(2)	3(2)-*e*	3(3)	3(3)-*B*	4	4-*f*	5(1)	5(1)-*g*
5(2)	5(2)-*f*	6(1)	6(1)-*g*	6(2)	6(2)-*C*	7	7-*C*
8	8-*h*	9(1)	9(1)-*i*	9(2)	9(2)-*l*	10(1)	10(1)-*m*
10(2)	10(2)-*n*	10(3)	10(3)-*o*	11(1)	11(1)-*i*	11(2)	11(2)-*j*
11(3)	11(3)-*k*	12(1)	12(1)-*k*	12(2)	12(2)-*o*	13	13-*D*

All in all, the location of the emergency event will affect the number of evacuations in the exit. Different levels of emergency events, the number of open emergency exits is different, and the staff should adopt different evacuation plans. We will give the final recommendations in the form of a decision tree similar to the following:

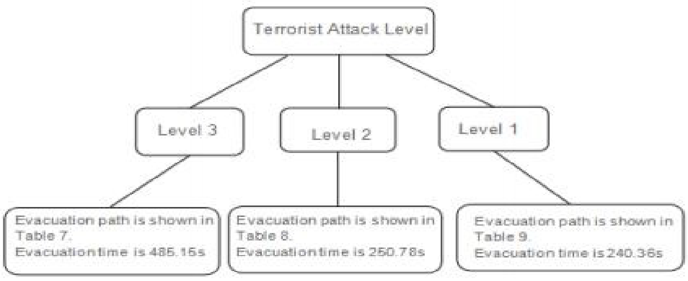

Figure 6. Evacuation plans for terrorist attacks at all levels.

ISSN: 2710-0588

7.2. Simulation Analysis and Suggestion of Model Scheme

(1)The effect of evacuation and evacuation interval

in the context of different terrorist attacks and different levels of harm, change the total number of evacuations, get the evacuation time-person number curve. Change the evacuation interval, get the evacuation time-dissipation distance curve;

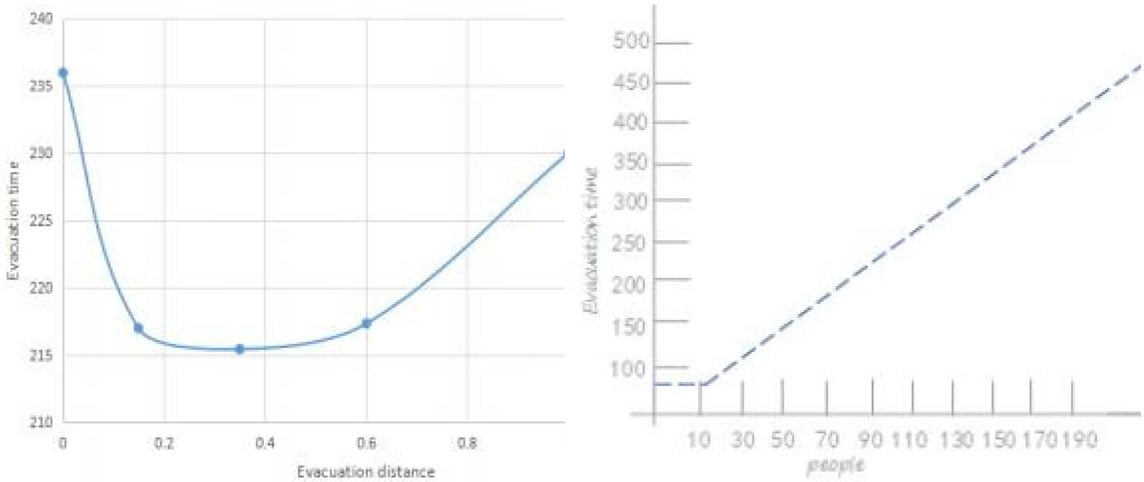

Figure 7. Evacuation time-person ˛time-dissipation curve.

When the total number of evacuations has gradually increased, the total time required for evacuation of all employees has increased in a fold line. This shows that when the waiting situation is not considered, the total time of evacuation is basically proportional to the total number of evacuations; Two or three inflection points on the same fold line occur when the upper and lower evacuation teams meet and the evacuation teams on the same floor meet. As the waiting time increases gradually, the total length of evacuation increases; When the total number of evacuees continues to increase, the waiting time will gradually become the most important factor affecting the total evacuation time.

(2)The effect of baggage obstacles

Whether pedestrians carry baggage in the evacuation process, will not only show different walking speed, but also lead to some pedestrian baggage dropping or aban- doned in the crowded state. These baggage left in the corridor will become obstacles, which will force subsequent pedestrians to reduce the speed to prevent tripping, the types and sizes of luggage people carry during their travels are shown in the table.

Table 11. Statistical value of he types and sizes of luggage people carry

Luggage Types	Percentage	Frequency	Diameter
Not carrying	5.0	15	0.45-0.60
Packet	28.4	86	055-0.70
Backpack	34.8	105	0.70-0.85
Handbag	6.3	19	0.85- 1

Relevant survey data show that, in case of emergency, different sizes of luggage will have a differentiated impact on evacuation speed of different types of people, and there is a difference in walking speed between men and women when they carry different types of luggage. With different types of luggage, the change range of pedestrian speed is different. The chart below shows the effect of baggage barriers on speed in both men and women.

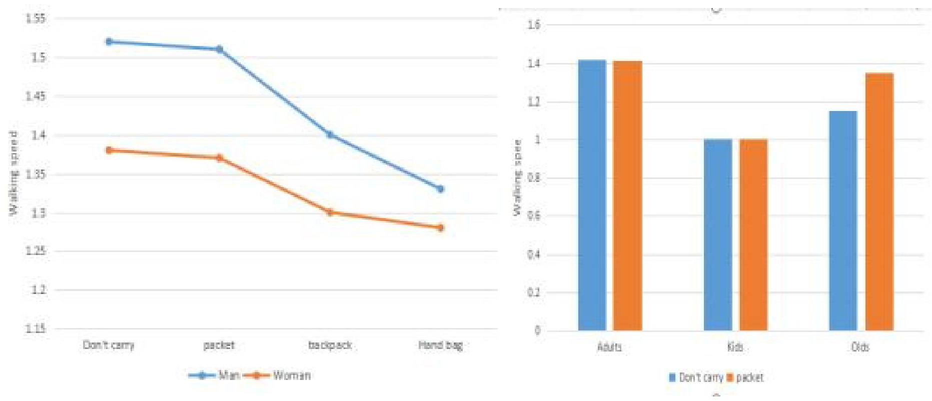

Figure 8. Walking speed between men and women , kids, the old and adults.

In the evacuation process, the elderly and children are relatively vulnerable. There is no significant difference in speed between the elderly and the children without lug- gage or carrying only small pieces of luggage, which can be considered separately. The figure above shows the speed change of the elderly and children without carrying or carrying small pieces of luggage, and the comparison with the speed of adults.

(3)Forecast future visitors

After analyzing the number of exhibitors at the Louvre from 1988 to 2018, the neural network was used to input the year, and multiple fitting operations were performed to obtain the relationship between the corresponding numbers as follows:

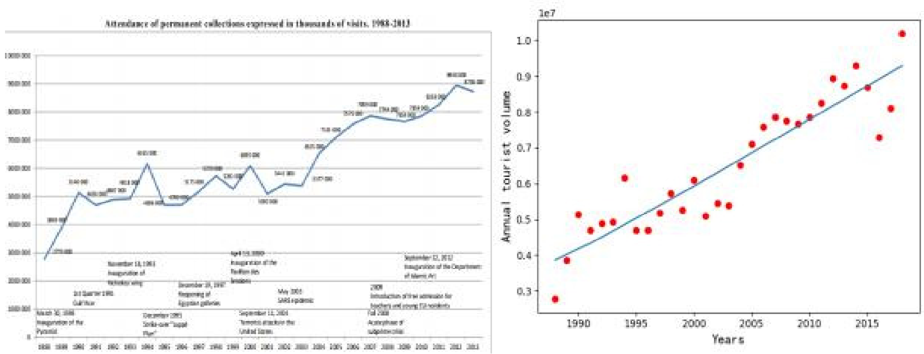

Figure 9. Map of the second floor.

The neural network was used to input the year, and multiple fitting operations were performed to obtain the relationship between the corresponding numbers. And the number of the visitors will be 8685630 in 2019.

8. Conclusion

The model we adopted is based on the reasonable assumptions about the prob- lem, and the simplification do helps us with the solving of the model. We only study on the average probability, which simplifies the problem and helps us easily to solve the problems. The model has a wide range of applications and can be used in all kinds of places without interruption when evacuees pass through the exit.

The body thickness of evacuees, the sum of spacing, the speed of evacuation and the minimum width occupied by evacuees are all constant, which is the average value. In reality, the model is

ISSN: 2710-0588

constantly changing, and only has generality. In the case of dense personnel, the layout of the site and the optimization of the evacuation path are not considered, and the evacuation of the bottleneck point in the evacuation path can be considered. The optimization of evacuation path should be further considered when the distribution of personnel relative to the location is relatively loose or the evacuation path is more complex.

Due to the phenomenon of pedestrian congregation and the unevenness of e- vacuation passages, the exit forms an arched person flow. If the intensive crowd can- not be guided and evacuated in a timely and effectively, it is easy to lead to malignant events such as crowding and trampling happen. In order to deal with the phenomenon of blockage, the number of staff guiding evacuation should be increased and efficient evacuation should be carried out; High-density passenger flow is formed at the corner of the evacuation passage due to the obstruction of metal fence and the occlusion of corner sight. It is necessary to avoid the equipment that obstructs evacuation in the passage, improve the average speed of passengers in the congested area and reduce the risk of trampling accidents; In emergency situations, there should be escape guidance from the narrow to wide space to avoid pedestrian catch-up; the metal fence in the evacuation channel should be quickly removed to prevent escape obstacles; hanging mirrors should be in- stalled at corners to solve the problem of congestion caused by the obstruction of sight; At this time, in order to guide the crowd to carry on the orderly evacuation, the evacuation organization and site manager should release the information which is help- ful to improve the evacuation efficiency, such as the location of the safe exit and dan- gerous source, the use of the evacuation route and so on.

Acknowledgments

Natural Science Foundation.

References

[1] Haque C E, Perspectives of natural disasters in East and South Asia, and the pacific island states: Socio-economi Correlates and needs assessment[J]. Natural Hazard- s, 2003, 29: 465-483.

[2] Zhao Daoliang, Yang Lizhong, Li Jian. Exit dynamics of occupant evacuation in an emergency[J]. Physica A, 2006, 363(2): 501-511.

[3] Zhao D L, Yang L Z, Li J, et al čő Relationship betwagn performance-based design of building exits and state transition of pedestrian flow during occupant evacua- tion[J]. Journal of Fire Protection Engineering, 2006, 6(4): 269-281.

[4] Flood, J. A. (2005). Socio-legal ethnography. In R. Banakar & M. Travers (Eds.), Theory and method in socio-legal research. Oxford: Hart Publishing.

[5] Malik, I.H., Najmul Islam Hashmi, S. Ethnographic account of flooding in North-Western Himalayas: a study of Kashmir Valley. GeoJournal 87, 1265–1283 (2022). https://doi.org/10.1007/s10708-020-10304-2.

[6] Akerkar, S., Joshi, P. C., & Fordham, M. (2016). Cultures of entitlement and social protection: Evidence from flood prone Bahraich, Uttar Pradesh, India. World Development, 86(C), 46–58.

[7] Birkland, T. A. (1996). Natural disasters as focusing events: Policy communities and political response. International Journal of Mass Emergencies and Disasters, 14(2), 221–243.

[8] Chauhan, R., Ramanathan, A. L., & Adhya, T. K. (2014). Patterns of seasonal variability in granulometric characteristics of Bhitarkanika Mangrove–estuarine complex, East coast of India. Indian Journal of Geo-Marine Sciences, 43(6), 1083–1090.