A Study in Human Behavior Pattern and Application of the Designing for Escape Routes at Daegu subway fire

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Abstract

In this study, the author has researched human behaviors pattern in fire emergencies and escape routes of survivors during Daegu subway fire. This research provides the basic data of the existing underground space, progress of fire suppression and rescue. The Survey was executed twice from the train passengers of disasters. The train passengers were classified as passengers of NO. 1079, NO. 1080 and the passengers of NO. 1080. The escape routes followed by human behaviors in fire emergencies may be contribute to the safest escape type of occupants while firing in underground space. This planning for the escape routes should be integrated into space programming at the early stage of design.

1. Introduction

1.1 The purpose with the background of research

With the development of the industry, the human demands for the land increased continuously. Due to the limit of the ground space, the underground space is more and more complex, form the those factors, and the property and human life damages at a fire occurrence of underground spaces are considerably great compared to existing disasters.

In Korea, the Seoul Subway line 1 was opened in last 1974 and the subway have been operated with Pusan and Daegu, the subway was related to a underground shopping mall and was developed as complex spaces and the spaces have been utilized by a great number people. The underground space is utilized also for the people reside; the necessity about the safety countermeasure of the underground space has been enlarged. Consequently, there are the efforts to minimize a human life and property damage from similar

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underground fire occurrence or misfortune disaster.

The egress routes of the fire are the space plan to make for the safety zone, to protect the human from various disasters and to escape by oneself without others aids. But It does not have the reliability and the technique for those disasters.

In this research, we investigated about survivors of the Daegu subway fire and analyzed the factors of the influence of human behavior and egress methods in the underground space fire. Therefore, this research tries to offer the knowledge for the egress plan and basic data of the escape routes that design for needs.

1.2 The range and method of research

In this research, we analyze about a escaper behavior pattern and escape type at the Daegu subway fire tragedy to happen at February 18, 2003. Therefore we try to study egress routes that design to deal with the egress situation of the underground spaces at the fire occurrence.

In this research, we analyzed a making up questions, investigation data which execute twice from the survivors, 146 persons among subway coach passenger and the people at the Daegu subway station in fire at February 18, 2003. The making up question items were composed of 60 questions with objectivity questions and subjectivity questions to find out the recognition ability of the disaster for the accident appears, egress types and egress situation.

2. Theoretical consideration

2.1 Overview of the Daegu subway

The line 1 of the Daegu subway has been opened at May 1998, it was 25.9km of total extension and connected from the Jincheon station to the Daegok station. The subway train of the line 1 was composed of 6 coaches, control car and power car, and total length is 108m. Train coach 1, 6 are control cars and train coach 2, 3, 4 and 5 are power cars. The data of subway train is as follows.

Table 1. Overview of subway train of the Deagu

Length	Height	Width	Total numbers of person to take
18m	4m	2.75m	1965

2.2 Overview of the Daegu subway fire

There was the fire in the Junganglo station of the Daegu subway line 1 at February 18, 2003.

The fire broke out at coach #1 of No.1079 subway train that was operating from the Jincheon station to the Anshim station. The breaking out time of the fire was about 9:53am and the time of putting out the fire was 1:38pm. The cause of the fire was the commitment of fire with the arson that was used 4 liter of volatile material. After the fire of no.1079 subway train, No.1080 electrical train in the opposite direction was stopped at the Junganglo station and the fire was spread out to No.1080 subway train. In the breaking out time of the fire, the numbers of passengers were supposed to about 640 persons. The human damage from the fire was total 440 persons that consisted of 192 persons of the dead, 148 persons of injured. The dead persons consisted of 142 persons in subway train, 49 persons from out of subway train, and 1 person from no recognition. The distribution of the persons in subway train was as follows.

Table 2. The distribution of the dead persons in subway train (142 person)

No.1079	**No.1080**					
	1	**2**	**3**	**4**	**5**	**6**
2	2	7	2	13	54	62

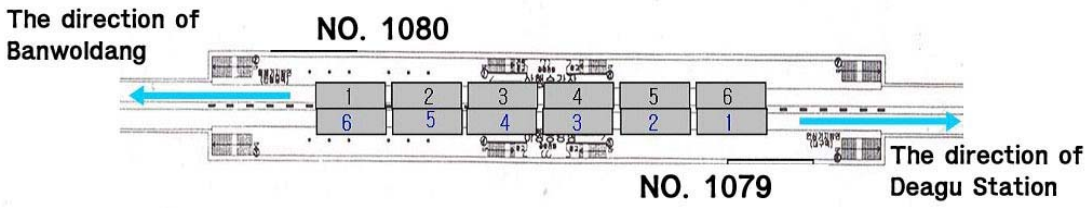

Figure 1. Stop location of subway train at Junganglo station

2.3 A Junganglo station of the Daegu subway

The Junganglo station of the Daegu subway line 1 was at distance of 700m with nearby the Banwoldang station and the Daegu station. And the Junganglo station was located in the center of town of Daegu city, traffic is complex, there were many passengers and it was connected with the underground shopping malls.

There were the stop location of the electrical train and the location of the exit to lead from the platform to 2nd underground floor in figure1. The structure of the Junganglo station was the steel-concrete structure, it was consisted that the platform is on the 3rd underground floor, the ticket gate and lobby are on 2nd underground floor, and the space of 1st underground floor is used as a lobby and connected the Junganglo underground shopping malls.

The coach 3, 4 of the subway train was located the middle stairs, each end of the subway train was located the edge stairs to lead upstairs. The longest distance between the subway train and stairs is 60m, the fire originated from coach 1 of the no.1079 subway train. The shortest moving distance, not turning back, from the platform of 3rd underground floor to ground exit is 120m in case of no.1080 subway train. And the longest moving distance is 171m. Passengers can move between the shortest distance at coach 1, and the longest distance at coach 6. The moving time of normal adult man is required over 2 minutes from the coach 1 of no.1080 subway train to the ground exit, and over 3minutes from the coach 6 of no.1080 subway train to the ground exit.

Table 4. The average walking speed

Type	m/s	Type	m/s
Slow pace	1.0	In darkness (know well place)	0.7
Fast pace	2.0	In darkness (not know well the place)	0.3
Average pace	1.3	Crowd walk pace	1.0
Crawl about on hands and knees	0.5	Quick step	3.0

2.4 Behavior habits of the human

We can find out the behavior patterns of high frequency when we observe in detail the behaviors as individual or group of the daily life pattern. There are four behavior habits "keep to the left", "turning left", " a shorter way", "turning back the way" as a general behavior pattern of human.

Besides, the general behavior patterns of escaper at the fire are found out four behavior patterns, such as choices of familiar route, inclining to the bright direction, choices for the shorter way, following the other people.

2.5 Egress characteristics of the underground space

The physiological and psychological influence on human is uncertainty in comparison with living of ground space to underground space. The egress characteristics of the underground space fire are as follows.

First, human is confused by darkness from interruption of electric power and it is

difficult to find out the egress direction when the underground space is on fire. Besides, it is difficult to confirm the location and direction due to lack of symbol and optical interception for the outside through the human eye.

Secondly, if the ground is used for egress space, the egress method of the underground space differs from the egress method of the ground because the moving direction of smoke is identical that is a matter.

Thirdly, it is apprehended that the situation can't make a prediction like the panic by people to yield to vague terrors about the underground space itself.

Fourthly, users are many and unspecified persons, they are not sufficient to recognize about spaces.

Lastly, users have no sense of direction due to paths of complicated breaking curve and the form of the plane; they are easy to wander from the route in the underground space.

3. The method of the investigation

In this research, we investigated the subject of the escaper of 146 persons among the survivor of 148 persons at the Daegu subway fire. The methods of the investigation are the making up question and interview about behavior type and egress behaviors at the fire occurrence. First, we executed the interview and the first making up questions in the object of the escaper of 146 persons. Through this, we excluded 46 which we do not have the consistency and objectivity among the response persons. We executed the second questions with 100 peoples except 46 peoples, then we analyzed this result. 100 persons consisted of 5 staffs and 79 peoples who remember the electric train number, 16 peoples who didn't remember. There was majority of deceased in electric train No.1080 and some person of the responder existed in coach 5, 6.

Table 4. The distribution of riding spot for survivors

Location	No.1079	N0.1080		
		Unit 1,2	Unit 3,4	Unit 5,6
The number of persons	9	27	34	9

Staff: 5 person, Don't remember: 16 person

The content of investigation is about the egress method and the survivor's own behavior when the fire got up. The analysis was composed of the making up questions once and an interview, the statement of the person in questions.

4. Analysis of egress behavior patterns

4.1 The frequency of usage and the ability to recognize

We investigated a Junganglo station usage number and a subway usage frequency of the escaper. There was majority responder, who use the Daegu subway line 1 over one time per a day, over the half replied that they used the subway over two times for the round trip per a day. There was secondly bigger numbers of responder who use over three times per a week. There were included response from subway staffs and the people didn't reply.

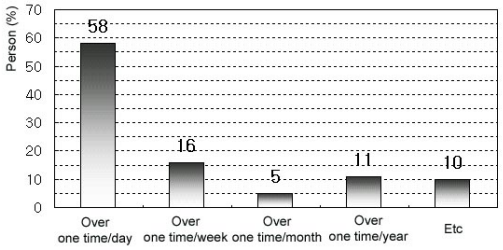

Figure 2. The frequency of usage the Daegu subway

Figure 3 was showing the response of the Junganglo station, which was broken out the fire. There was many of responder, who use the Junganglo station over one time per a day and there was many of responder, who use over two times per a day. There were included response of subway staffs and the people of no reply and the four people who used first time the Junganglo station. There was one person who often used it on vacation and sometimes on school term.

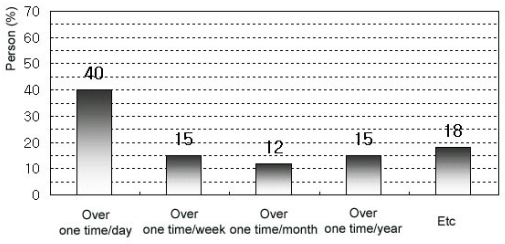

Figure 3. The frequency of usage the Junganglo station

There are the results of the investigation at figure 4 about the ability to recognize of the Junganglo station routes of escaper. There was over 70% of responder who could find out the ground exit with and without the directional sign. This result was related to the frequency of usage the Daegu subway and the Junganglo station as stated above. There was many of responder who could find out the ground exit without the directional sign. There were included responses, "I can find out the exit if I know the route"(one person), "do not know at all"(four persons), "not reply"(three persons).

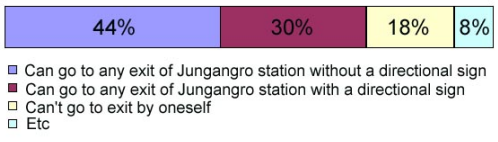

Figure 4. The ability to recognize of the Junanglo station routes

4.2 Behavior type before the egress

There were difference time gaps between fire occurrence of the electric train No.1079 and the electric train no.1080. Figure 6 is showing escaper's behavior after they recognize the fire. There was most many of responder, who responds to " a wait" and " the contact with the outside". And responder who immediately escaped was less than 30%.

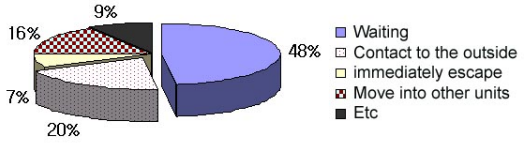

Figure 5. Escaper's behavior after they recognize the fire

There were the factors to decide egress in figure 7. The 41% of responders answered that the factor of decision to egress from the fire is "a smoke". Many passengers of coach 1, 2 of no.1080 subway train, which condition comparatively was better than other coaches, answered that they escaped by the guidance broadcast than any other responses. Other responses were "subway staff" and "at the sound of 'Do egress'".

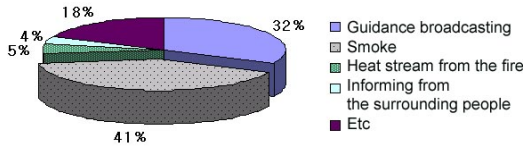

Figure 6. The factor to decide escape

4.3 Egress routes

The date shows that the egress routes are different from the initial standing points of the each occupant. In the case of the NO.1097, the date was collected without identifying each coach because the numbers of responder for the research were very few. The half of replier had no memory while escaping, between the responder. Base on the total responders, the higher ratio of the routes by the

numbers of escapers are followed: to the left at the B3 platform, to the right at the B2 ticket gate and to the left at the first floor waiting room.

A figure7 shows that the results of the cases, according to the actual egress routes from the expected egress routes and the case of turning back to the initial location after once trying to the various routes. The 47 people replied they didn't escape the routes what they expected and 17 people replied that they escaped the routes what they expected. The subway staffs were the majority among the 17 people. It means that the escapers had the knowledge of that underground space among the 17 people. The 11 people replied they didn't have any idea for escape route. The most of u-turned people happened at the B2, especially before passing by ticket gate on the B2, and B3 platform that was the most difficult and dangerous for the rescue. The reason for the u-turn was followed; the visual barrier from the smoke, no sense of stair location, missed escapers line, obstructed of the routes.

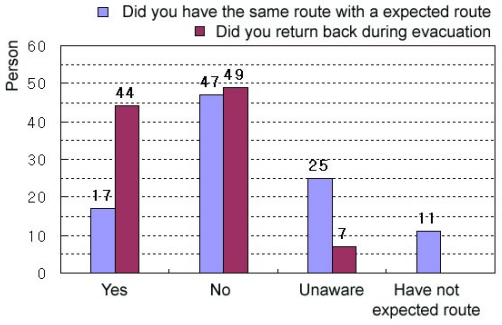

Figure 7. Selection of egress route

5. The characteristics of the egress and those applications for the egress

The Junganglo subway station consists of 3 story underground floors. The waiting rooms were located on the first and second underground floor, the platform was located on the third underground floor. It was complicated spaces because the first underground floor was connected to the underground shopping mall.

The figure 8 shows that the degrees of the visual barriers from the smoke and heat from the fire while people escaping through the B3 platform, B2 ticket gate, B1 waiting room and underground shopping mall to the ground floor from the subway fire spot of the train coach. The survivors replied that there were the highest visual barriers at the B3 platform and it was getting reduced at the higher floors. There were also serious visual barriers at the waiting area of the B1. But the actual degree of the visual barrier was almost similar because the survivors couldn't have enough time and clear conscious to identify the degree of visual barrier while escaping from the fire. There is people who had over 5m sight capability were only 2~4% form the escapers of train 1079 because they escaped early stage of fire.

The research shows that there are difficulties to escape from the extremely high temperature enough to melt whole plastic materials of B1 at the firing routes. But also the degree of heat temperature was similar in terms of human sense even though the numbers were getting reduced at higher floors for the heat barriers from the data.

5.1 The method of egress

The research shows that there is the highest number for the method of escape was the case of escaping followed by the wall through the touching and the second ratio was escaping followed by leading people through the holding clothes and part of body. But the research shows that the guide rail and hand rail couldn't enough lead the people to the stairs or egress route because there was no belief for the correct

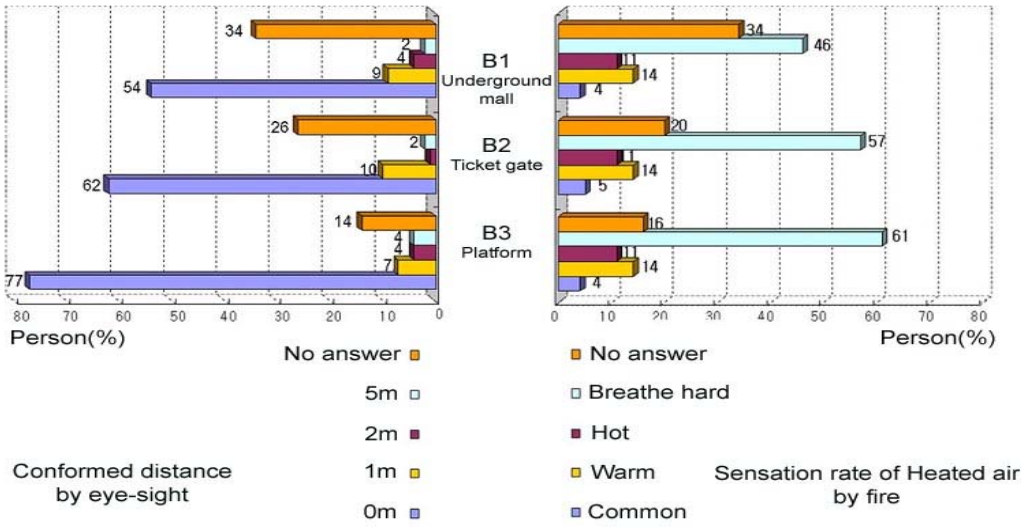

Figure 8. Smoking and heating according to the level difference in the case of escaping

escaping routes and hard to approach to the guide rails like holding peoples' clothes.

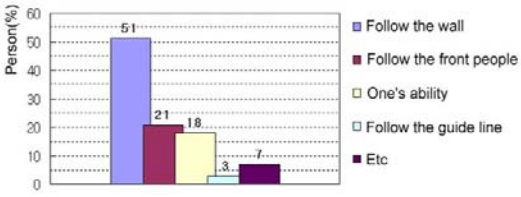

Figure 9. Method about moving forward

5.2 Analysis based on egress devices

There are the higher percentages to help egress was the devices such as inducing light, commercial light boards, flash light as 49%, the knowledge of the subway station was 20% and sounds were 13% among the repliers.

The most barriers to escape were visual obstruction and the next was smoke. The visual barriers and smokes made escapers to loose the sense of direction and these factors gave the escapers difficulties to escape. There were other minor factors such as stairs, ticket gate, fire shutter, complicated subway spaces, columns and piers, chaos peoples.

The figure 10 shows the factors of barriers on the third platform underground floor that has the longest distance as the egress route. The difficult factors to escape at the third underground floor were the visual barrier and narrow width of platform. There are minor factors such as columns and piers, commercial boards.

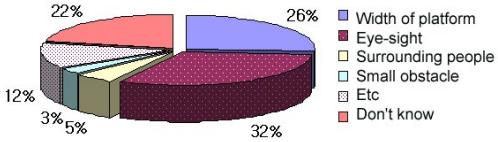

Figure 10. Interference factor of B3

The 48% escapers said that the stairs made them the most obstruction to escape, and the height was the more influence factor to escape than the width of the stair in detail as the figure 11.

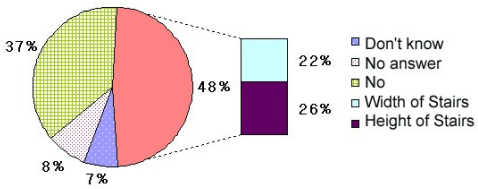

Figure 11. Obstacle at the refuge staris

5.3 The inducing light

The most of survivors couldn't see the emergency inducing lights after starting to escape from the initial spots and the escapers couldn't get the help from the inducing lights either. It means that the inducing lights couldn't make the role of their own because of smoke obstruction from electricity power off and firing. It should be considered that the location and methods of inducing lights and devices are used by not only visual factor but also audible and tangible.

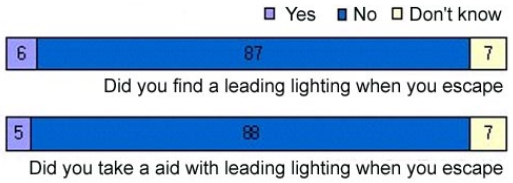

Figure 12. Response of inducing light

6. The conclusion.

The result of the survey to apply to 146 survivors. The responder is 100 persons. The half of the survivor used subway more than once a day. The total number of the survivors used Junganglo station more than once a day. Also more than half of the responded people have the ability to exit without exit signboard. But most of people in fire, they try to wait or contact to outside instead of escaping. More than half of the responder informed that the expected refuge route did not match with the actual refuge route. Thus refuge guidance plan is very important. The tendency of touch stairs, wall as the refuge method, it informed us a guideline to install the exit lights along the wall. It shows that visual indication is the most helpful item and visual barrier is the most interference to egress. Greater part of the interruption to escape is the loss of the direction to escape. We need to install with suitable emergency guidance devices according to the fact we have. The device should be equipped with not only visual indication but also with tangible and audible. Even though the ground floor is the main exit as the refuge space, the underground plaza could be used as a refuges area and it should be considered on the characteristic of the underground space. The expert staff of the emergency should be on duty against any case of firing at underground space. We should consider the facts of the escape route intersects, smoke stream, refuge, activity direction of the fire fighting at the same time.

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