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Map UI Design of IoT Application Based on Passenger Evacuation Behaviors in Underground Station

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***Abstract*—**When the public space is in an emergency, how to quickly establish spatial cognition and emergency shelter in the closed underground space is the urgent task. This study takes Taipei Station as the research base and aims to apply the use of Internet of things (IoT) application for underground evacuation mobility design. The first experiment identified passengers' evacuation behaviors and spatial cognition in underground spaces by wayfinding tasks and thinking aloud, then defined the design conditions of User Interface (UI) and proposed the UI design. The second experiment evaluated the UI design based on passengers' evacuation behaviors by wayfinding tasks and think aloud again as same as the first experiment. The first experiment found that the design conditions that the subjects were most concerned about were "map" and hoping to learn the relative position of themselves with other landmarks by the map and watch the overall route. "Position" needs to be accurately labeled to determine the location in underground space. Each step of the escape instructions should be presented clearly in "navigation bar." The "message bar" should be informed of the next or final target exit. In the second experiment with the UI design, we found that the "spatial map" distinguishing between walking and non-walking areas with shades of color is useful. The addition of 2.5D maps of the UI design increased the user's perception of space. Amending the color of the corner diagram in the "escape route" also reduces the confusion between the symbol and other diagrams. The larger volume of toilets and elevators can be a judgment of users' relative location in "Hardware facilities." Fire extinguisher icon should be highlighted. "Fire point tips" of the UI design indicated fire with a graphical fireball can convey precise information to the escaped person. "Fire point tips" of the UI design indicated fire with a graphical fireball can convey precise information to the escaped person. However, "Compass and return to present location" are less used in underground space.

***Keywords*—**Evacuation behaviors, IoT application, map UI design, underground station.

I. Introduction

MANY cities have responded to growing urban population density by actively developing underground spaces at public transportation hubs. However, any survey of previous news reports would indicate that loss of life and damage to property can result when emergencies occur in underground spaces. Taipei City's underground metro stations have suffered considerable damage caused by flooding from torrential rains. Swift evacuation of enclosed underground spaces is, therefore, a key component in public space design. Empirical evidence from emergencies in public spaces indicates that the primary concern of the general public is locating emergency exits and evacuation routes as quickly as possible. In addition to ground support provided by station personnel, applying existing technology to assist crowd flow is critical for successful public space design. Push technology actively provides information from servers to end users. Traditionally, users must actively search for information to receive it. However, Internet of Things (IoT) devices provide push notifications that can directly transmit information to end users' mobile devices. Countries worldwide have acknowledged the apparent advantage of the instantaneous nature of IoT devices for disaster detection and warning. An urgent task is to develop a mobile device user interface (UI) to guide the general public in underground spaces with precision and speed. Past researches [6], [7] have attempted to understand whether people can move freely within a specific space using wayfinding, a common behavior in daily life, and space cognition maps. Roger et al. identified four processes in wayfinding behaviors: orientation, route decision, route monitoring, and destination recognition [4].

1. Orientation: use of objects or landmarks in a person's surroundings and their relationship to the destination to confirm the present location
2. Route decision: selection of routes to arrive at the destination
3. Route monitoring: awareness and assurance that the selected route is the correct path to the destination
4. Destination recognition: confirmation of the target destination

Conroy stated that "wayfinding is the act of traveling to a destination by a continuous, recursive process of making route-choices whilst evaluating previous spatial decisions against constant cognition of the environment [1]." It showed that patterns of human wayfinding are not only a form of processing based on unilateral reception of information; rather, it is the result of a parallel process that involves continuous absorbing of information regarding surroundings and comparison of such information with mental cognition. Scholars proposed three cognitive map structures to assess the orientation of individuals within a specific space: 1) egocentric, which centers position based on the viewer's own location; 2) fixed, which uses a certain fixed point as a point of reference; 3) coordinate, which marks the position of specific elements with an abstract

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coordinate system [3].

Wayfinding is always relative because people are different. Therefore, emergency evacuation planning in public space design must consider the behavioral traits of individuals within specific spaces to provide the appropriate evacuation support.

Number	Type	Design
Indicator (3)		White background + text + human figure + arrowhead
Indicator (5)		Green background + text + human figure
Indicator (7)		Green background + arrowhead

Fig. 1 Types of evacuation direction indicators

Taipei Main Station is a station with aboveground and underground infrastructure jointly servicing the Taiwan Railway, Taiwan High Speed Rail, and Taipei Metro and is the primary transportation hub for the Taipei public transportation system. On average, the Taipei Metro station at Taipei Main Station handles 308,000 people per day, making it the busiest in the Taipei Metro system. This study selected the Taipei Metro station at Taipei Main Station as the representative space for evacuation mobility experiments. Currently, the most used signs in the Taipei Main Station evacuation indicator system are indicators 3 (422 installed), 5 (184 installed), and 7 (107 installed). If measuring the number of indicators used most at the exits on each floor, the top three are indicators 3 (188 installed), 7 (99 installed), and 5 (93 installed). Evacuation indicators are mostly suspended from the ceiling; however, several indicator 3 installations are on the wall.

Preliminary experiments investigated which types of emergency evacuation system installed in the underground levels of Taipei Main Station are more effective for evacuees and what sort of problems and situations individuals would encounter when using the emergency evacuation systems. The study selected specific floors as the experimental space and defined the routes, boundaries, and starting points for the experiment. A total of 14 individuals, seven men and seven women, participated in a simulated fire emergency and evacuation situation. Their task was to evacuate as quickly as possible from the starting point to any of the exits leading to the street level in accordance with their own preferences and following think-aloud protocols.

Preliminary experiments found that "data collection" in the think-aloud protocol was the most frequent of the three wayfinding phases. Route decision was the most frequent behavior in the assessing and deciding phase of wayfinding. Participants felt confused, lost, and a need to seek information regarding their surroundings at crossroads to assess which direction to go. When faced with transitions between floors, participants also felt confused when deciding between escalators and staircases. They generally based their evacuation movements on the text of the indicators. Therefore, providing complete information for evacuation at confusing crossroads can increase the efficiency of evacuation. Stairs were the main option for participants when they faced decisions regarding floor transitions, and the potential dangers posed by power failure in fire emergencies also influenced them in this choice.

Preliminary experiments provided a range of behavioral traits of persons engaged in evacuation and indicated that the numerous indicators currently installed in Taipei Main Station cannot meet the needs of evacuees or account for contingencies during emergencies. The future integration of the IoT and mobile phones should render a mobile device UI in such a way that it could provide accurate information for evacuation mobility. This study used an existing cartographical interface to provide an example of an interface design that could meet visual requirements. The interface was tested for efficacy through evacuation mobility experiments to understand how mobile device UIs can assist users moving in emergency situations.

II. Methods

This study comprised three parts, which are detailed as follows:

A. Current UI Assessment

To understand current evacuation mobility-based UI design, this study surveyed representative and highly rated navigation UIs to analyze dimensions of the different information bars of each interface and conduct statistical analyses on the type and quantity of the source images and function keys, which consisted of six categories of information: compasses, current location indicators, maps, notification displays, navigation displays, and function keys. Sections of the navigation interface were identified through color-coding according to the type of information shown. This study used K-means nonhierarchical cluster analysis, the most representative type of nonhierarchichal approach. Individuals were randomly divided into K-clusters, and individuals were swapped between clusters to minimize variation within each group and maximize variation between groups. After deriving a cluster ratio from data collection and clustering processes, multiple sets of evacuation interfaces were created in accordance with the area ratio of each informational display for the eye tracker experiment.

The eye tracker experiment in this study used the Gazepoint eye tracker for data collection by recording a range of eyeball movement data generated by the participants. Eye tracking is a technology that assists researchers in recording gaze points of individuals within a specific span of time and generates spreadsheet data that inform researchers of the sequence and pattern of eyeball movement. Eye tracking technology helps construct a user's attention distribution (when viewing a display) and the simultaneously recorded and processed eyeball movement data to produce objective UI data [5]. Gazepoint eye tracker technology objectively measures users' gaze and fixations when browsing a specific display interface and researchers can use patterns of eye movement to generate a range of eye movement visualization graphics. The experiment conducted for this paper analyzed the visual search strategies of participants interacting with five displays of different ratios.

Following the experiment, participants were subjected to semistructured interviews to collect their responses regarding a series of experiment-related questions to evaluate their degree of understanding of the interface, information provided through the interface, and visual appeal of the interface. The eye tracker experiment helped us identify the eye movement pattern, sequence, and duration of fixation of the participants when viewing five displays with different types of ratios. Participants were informed of the simulation scenario and were instructed to view the display interface content based on only their own decisions. The display showed participants one slide at a time for 10 seconds each. The steps of the experiment were as follows.

Step1. Eye movement fixation: Five sets of interface designs displaying four exits (a total of 45 images) were shown, including information on the evacuation scenario and evacuation tasks, to determine on what type of information and in what proportion participants would fixate their gaze when unprompted.

Step2. Eye Movement Experiment Prompts: Five sets of five interface designs regarding exit M7 (a total of five images).

First image: Participants were instructed to find their present location on the map. The prompt was designed to identify on what elements each participant fixated when attempting to recognize their surroundings.

Second image: Participants were instructed to look at the name of their destination. The prompt was designed to understand what information participants used as a basis when heading toward the next destination.

Third image: Participants were instructed to look at their target. The prompt was designed to understand what information participants would use as a basis when looking at a target exit.

B. Design Proposal

The area ratio of different notification bars was studied during interface assessments, which involved the collection of interface design examples. Screening for cluster analysis was conducted to choose the interface for experimentation. After reading experiment and post experiment interviews, a ranking based on preference and feedback was created. The conditions of the interface designs were summarized, and the elements of the interface design were defined and provided as experimental samples for mobility experiment testing.

C. UI-Assisted Mobility Experiment

Participants used a prototype created for the underground evacuation interface design proposal and a set of methods and steps tailored for the evacuation experiment to understand the behaviors that people exhibit during emergency evacuations. We studied the decision response and speech content based on the think-aloud protocol to understand the potential issues with movement and surrounding installations.

This experiment was set in the underground space of Taipei Main Station. The experiment defined floor B3 as the point of origin for the fire, and the wall displaying the information bulletin on floor B3 was designated as the starting point for evacuation. Participants departed from the starting point and looked for evacuation exits in the opposite direction of the fire. The designated exits were metro exits M7 and M8. The two exits were selected because they had the most turns and the longest paths among existing evacuation routes.

This experiment chose exit M7 and M8 as the experiment routes. The 32 participants split between the two routes, with 16 targeting M7 and 16 targeting M8. The participants departed from floor B3 of Taipei Main Station were equipped with information accessed through an interface on their mobile phones and evacuated B3 as quickly as possible to distance themselves from the fire's point of origin. They received push notifications when transitioning between floors and directions and relied on only the information provided by the mobile phone interface to evacuate via the designated exits leading to the ground floor. The researchers took a bystander’s perspective, adhering a noninterference policy, and recorded the participants with DVs while following them. Following the experiment, participants were shown the video footages to review their decision-making behavior and evacuation process. They also underwent interviews and responded to a set of research questions.

After the evacuation experiment, this study focused on the 11 functions of the interface and their respective icons, emphasizing testing the recognizability and understandability of the following: turn icons, staircase icons, compass icon, return to present location icon, fire extinguisher icon, lavatory icon, phone booth icon, elevator icon, navigation bar, target exit icons, point of origin icon (in this case for fire). Participants were asked whether they had used each of the 11 primary functions during the evacuation simulation. Each participant was also asked to rate the degree of helpfulness of each function on a five-point Likert scale. The results of the interview were collated and analyzed.

III. Results

A. Current Interface Assessment

This study collected 20 highly rated and representative navigation interface program, and analyzed the seven types of information displayed within the coverage areas of different information bars while the interface was in navigation mode. The types of information displayed comprised the compass, present location, map, notification bar, navigation bar, menu, and function keys. The results show that map bars occupied 33.2%–82.2% of the display, whereas navigation bars covered 3.3%–50.0%.

This study applied a K-means clustering analysis algorithm to divide each composition into groups, deriving five clusters with the averages visualized in Fig. 2, which illustrates an interface combining the five types of information for the eye movement experiment.

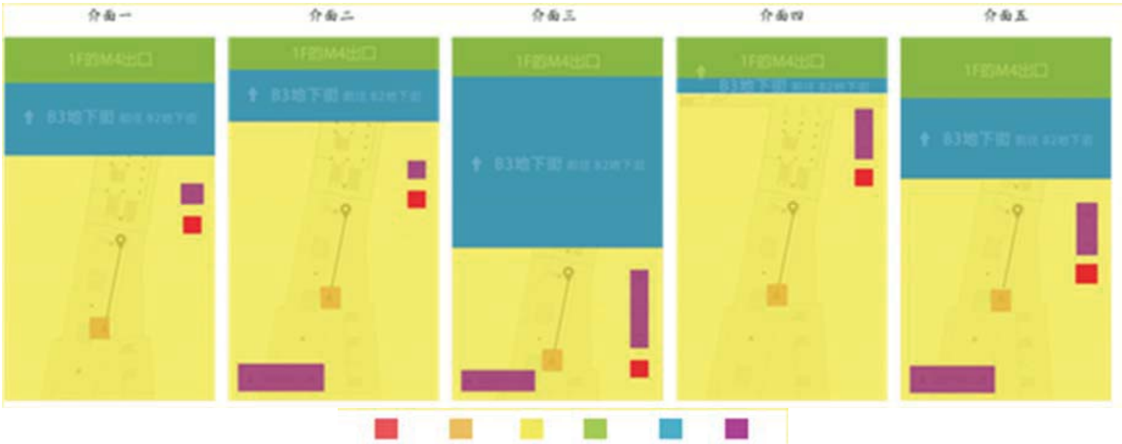

Fig. 2 Experimental design concept for each icon

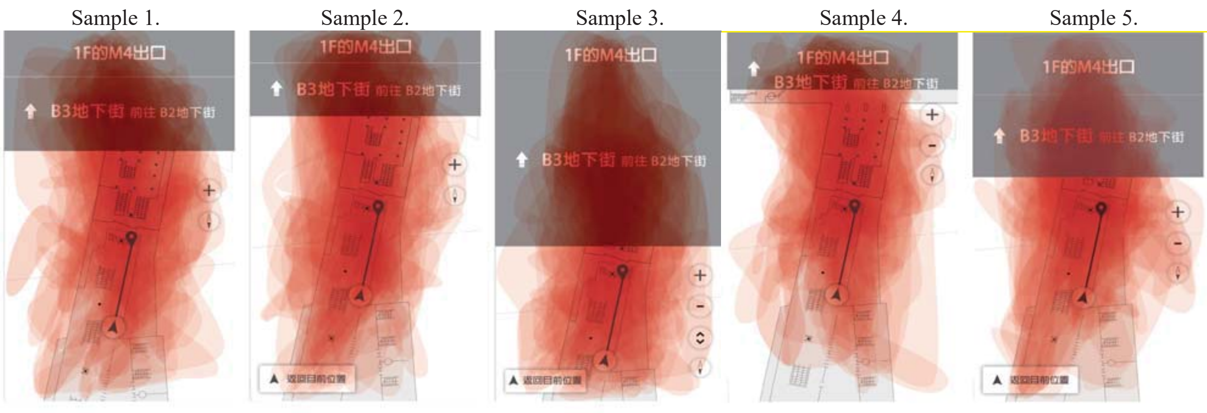

Fig. 3 Eye movement experiment results for five interfaces with heat map overlay

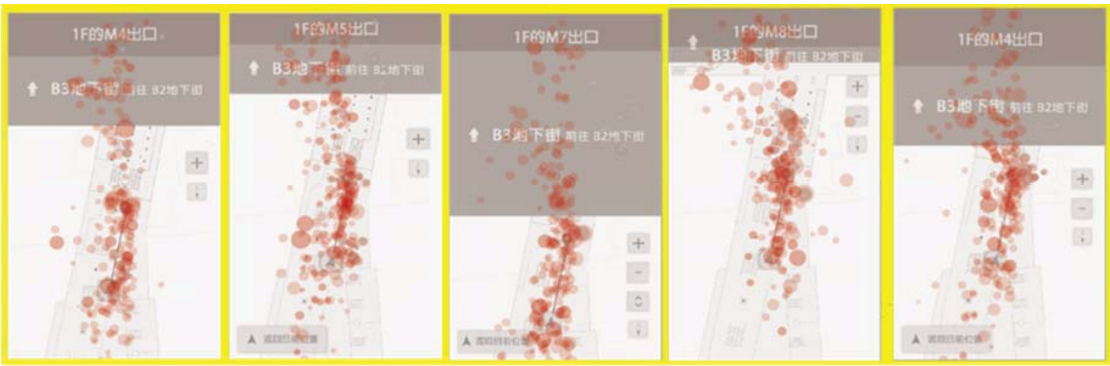

Fig. 4 Bee swarm overlays of fixation points

A heat map overlay was used to visualize participants' line of sight when viewing the interface, with the map and the evacuation route being the more frequented sections. The overlay indicates that participants viewed the navigation bar and the map more frequently than they did the notification bar. When viewing the navigation bar, the focus was on the text, whereas when viewing the map, the focus was on the route. The positioning of the "return to present location" key affected the preferred areas of vision for the participants.

Figs. 3 and 4 show the fixation points of the participants when viewing the interface, with the size of the dots indicating the duration of the gaze. The bee swarm overlay in the figure shows participants' focal points viewing the interface. The experiment found that participants were fixated on the present location and route. Participants showed more interest in text messages when viewing the navigation bar, and their primary focus was the map, followed by the navigation bar and notification bar.

In this study, the participants were asked to view five interfaces during the eye movement experiment. The eye movement data were collected and analyzed in terms of six eye movement indicators, including the information Bar (Inf), navigation bar (Top), map (Map), function keys (Fun), compass (Com), and present location (Loc). Analysis on the average duration of fixation, fixation count, and saccade count ratio shows that the location with the highest average duration of fixation was present location, followed by the information bar, navigation bar, and map.

For fixation count, present location was the highest, followed by the information bar, navigation bar, and function keys. The fixation count for compass was almost equivalent to that for map.

B. Saccade Count Ratio

Saccade count was highest for present location, followed by the information bar, navigation bar, function keys, and compass. Map had the lowest saccade count.

Finally, 16 participants were asked to conduct a preference survey for the five interfaces, ranking them from most preferred to least preferred, with equidistant values, and the average score for each interface was calculated. The sum of the scores corresponding to the rankings assigned by the participants was then divided by 16 (total participants), deriving a final mean score (x), as indicated in the formula that follows. For example, the top-ranked interface in this experiment (Interface 1) had a sum score of A = 108; after division by 16, the average score x = 6.75 was derived. Variable x_n represented the score of participant n, and f_n is the score corresponding to the ranking. The final average score is:

$$\overline{X} = \frac{x_1 f_1 + x_2 f_2 + \cdots + x_n f_n}{f_1 + f_2 + \cdots + f_n} = \frac{\sum xf}{\sum f}$$

Of the male participants, 62.5% chose Interface 1 as the preferred interface. Male and female participants chose Interface 3 and Interface 4 as the worst interfaces. Additionally, 37.5% of participants chose Interface 1 as the most understandability interface.

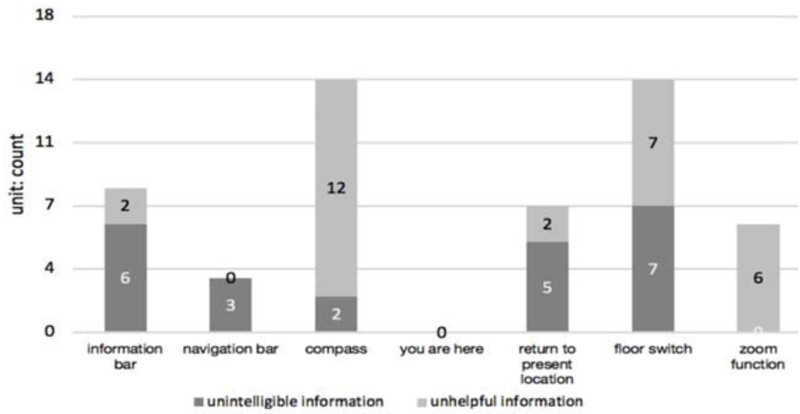

Fig. 5 Participant feedback on confusing and unhelpful information

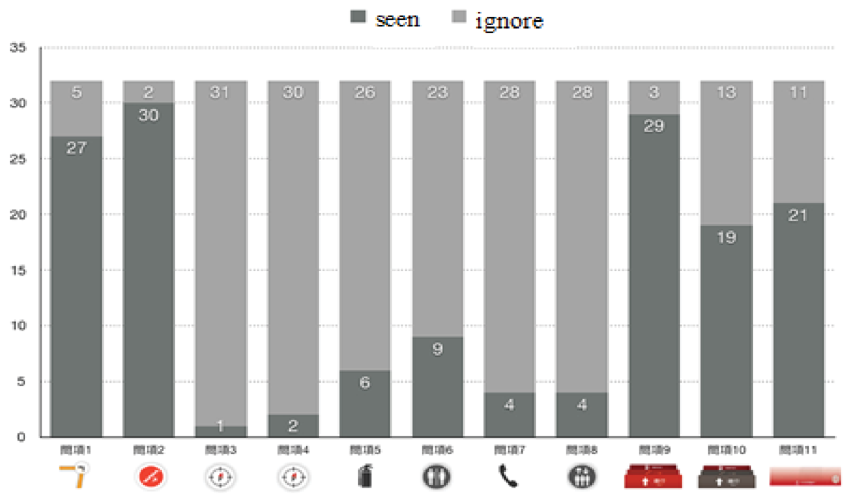

Fig. 6 Understandability of different functions of the interface

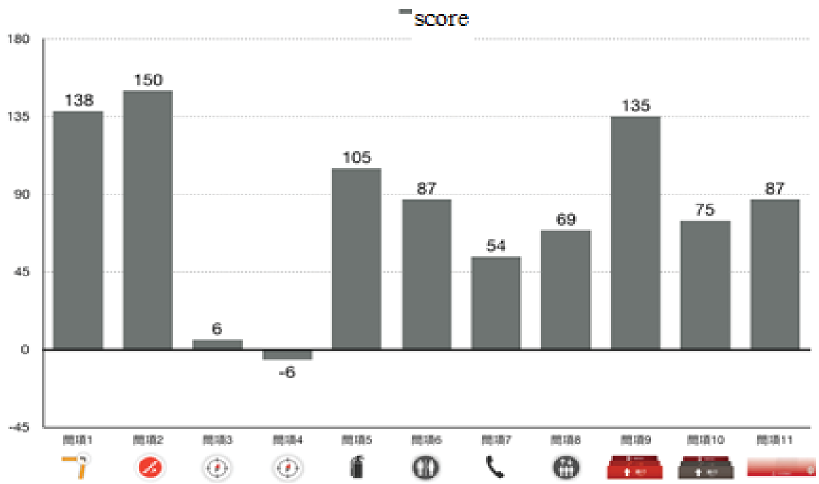

Fig. 7 Degree of contribution to evacuation according to function type

The participants also mentioned in post-experiment interviews that the compass, floor information, and zoom function were relatively unhelpful. In particular, they expressed confusion with the floor function, and believed the information from the information bar to be confusing.

Participants felt that some information was lacking, including the distance and location of the emergency, location of fire safety equipment, and distance remaining to the exit.

Participants were asked to complete a Likert-scale survey to assess the degree of contribution of each function of interface to the evacuation process.

Participants considered the floor transition diagram (Question 2) the most helpful for evacuation. Additionally, participants thought one escape path in the interface would have been sufficient. Less attention was given to functions other than the escape route indicator.

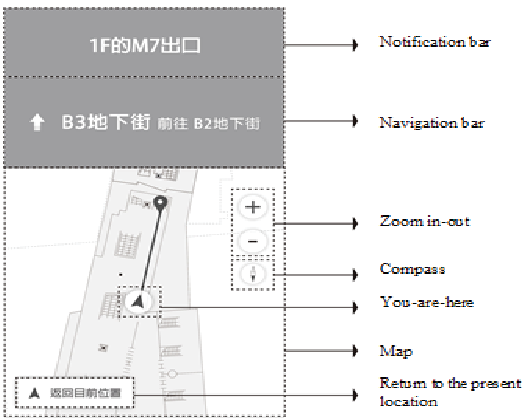

Fig. 8 Interface information layout

C. Design Proposal

This study chose the top-ranked Interface 1 as the model for interface design.

The interview regarding the understandability of different types of interface indicated that the participants were concerned with whether they could orient themselves using landmarks on the map and whether they could have an overview of the entire evacuation route on the map. "Present location" should be clear and precisely marked to provide accurate orientation for an individual. The instructions in the "navigation bar" should be clear and visible to help users understand evacuation steps as quickly as possible. The instructions in the "information bar" should provide evacuees with information on the next target and the final destination. Most participants also responded that the function keys and compass were not helpful for evacuation.

An interface prototype based on the necessary improvements highlighted by this study underwent experimental trials to assess its functionality. The design features are as follows.

1. Interface color: the interface used light red and orange as basic colors for association with warnings and alerts.
2. Notification bar: Evacuees received target destination prompts in text, and emergency evacuation icons were used to increase understandability to help evacuees during emergencies.
3. Navigation bar: Evacuees received instructions in sequence and vertical formats, with push notifications enabled; thus, they could have a clear view of both the present and the future courses of action and prepare their evacuation strategies accordingly.

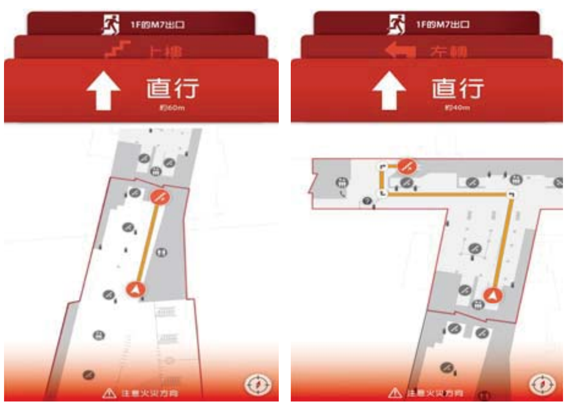

Fig. 9 Design proposal

4. Spatial mapping: Accessible areas and inaccessible areas were designated as light grey and dark grey, respectively. The floor of the evacuee's present location was contoured to distinguish it from other floors.
5. Evacuation route: Bright colors were used to mark the present location, present route, and floor transitioning prompts to distinguish between the different levels, floor plans, and routes. Turn indicators were placed on diverging routes to assist the evacuee in making turns during an evacuation.
6. Compass: A new function design integrated the compass with the "return to the present location" function.
7. Facilities: The interface included indicators marking the locations of facilities, such as elevators, lavatories, and escalators to serve as landmark reference points.

IV. Discussion

This study conducted an emergency mobility experiment with 32 participants, each equipped with a designed UI for a mobile phone application. A series of actions that the participants performed during the experiment were encoded. The encoding categories were derived from Passini's three phases of wayfinding, dividing participants' thought processes into three types: information gathering, decision-making, and decision execution.

The encoded behaviors of the 16 participants designated to exit M7 showed the following traits. In the data collection category, the code Ipr (viewing mobile phone interface–viewing map route) had the highest occurrence, followed by Ipi (viewing mobile phone interface–viewing icon) and Ie (following personal experience). In the "decision-making" category, Ddc (assessing the direction of movement–choosing an accessible route) had the highest occurrence, followed by Ddd (assessing the direction of movement–following pathway). In the "decision execution" category, Ed (questioning decisions) had the highest occurrence at 14 instances, followed by Ele (floor transitioning–taking the escalator).

The encoded behaviors of 16 participants designated to exit M8 showed the following traits. In the "data gathering" category, the code Ipr had the highest occurrence, followed by Ipi. In the "decision-making" category, Ddd had the highest occurrence, followed by Ddc. In the "decision execution" category, Ele had the highest occurrence, followed by Els. The results indicate that members of both groups began by first gathering surrounding information and subsequently comparing with the map from the mobile phone interface. Because of the differences in directionality and the number of passengers using the two exits, the decisions made and executed varied between the two groups.

32 participants used "descriptive segment illustration," "descriptive marking and floor illustration," "descriptive reference point illustration," "descriptive behavior and action illustration," and "descriptive interface element illustration" to create cognitive maps. "Descriptive reference point illustration" is used the most. Over half of participants used two types of cognitive mapping.

Wayfinding Phase	Code	Behavior	
Gathering information	Ipw	Viewing mobile phone interface	Viewing navigation text
	Ipi		Viewing navigation indicators and icon
	Ipr		Viewing map routes and information
	Ii	Viewing icon on site	
	Ie	Processing information based on personal experiences	
Decision making	Dlt	Correlating with on-site reference points	Elevator
	Dlr		Lavatory
	Dla		Commercial boards
	Dlp		Metro platform
	Dlc		Information kiosk
	Dls		Staircase
	Dlg		Railings
	Ddc	Assessing direction of movement	Choosing an accessible route
	Dds		Choosing a safe route
	Ddf		Following a crowd
	Ddd		Following a pathway
Decision execution	Els	Transitioning between floors	Taking the stairs
	Ele		Taking the escalators
	E?e	Lost	Interface not reflecting actual surrounding
	E?o		Barrier blocking access
	Ed	Questioning decisions	

Fig. 10 Evacuation experiment code chart

A. Evacuation Mobility Experiment

Regarding the category of decision execution, when choosing the escalator for transitioning between floors, most participants made an immediate decision when approaching the floor transition point. In particular, because of the visibility of the escalator at the turning point near the station gate, M8 participants were more prepared to decide the method of floor transition for themselves than M7 participants did.

Most participants hesitated at turns, including at the transitioning escalator between floors B3 and B2. Participants who assigned to exit M7 hesitated before or immediately after passing through the station gate because their line of sight was obstructed by the information kiosk located along their evacuation route. Some members of the M8 group were hindered passing between the large pillars at the turn where they transitioned from floors B1 to 1, resulting in multiple occurrences of hesitation. Therefore, hesitation occurred when evacuees changed the direction of their routes or when their line of sight was obstructed.

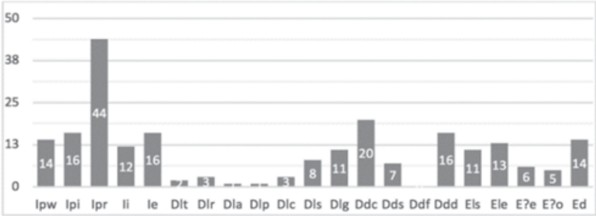

Fig. 11 The encoded behaviors of the participants designated to M7

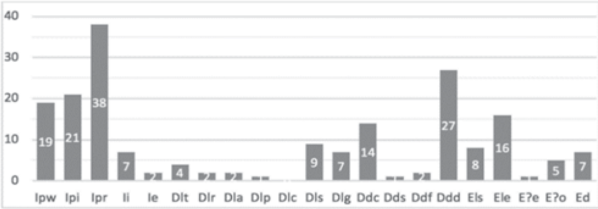

Fig. 12 The encoded behaviors of the participants designated to M8

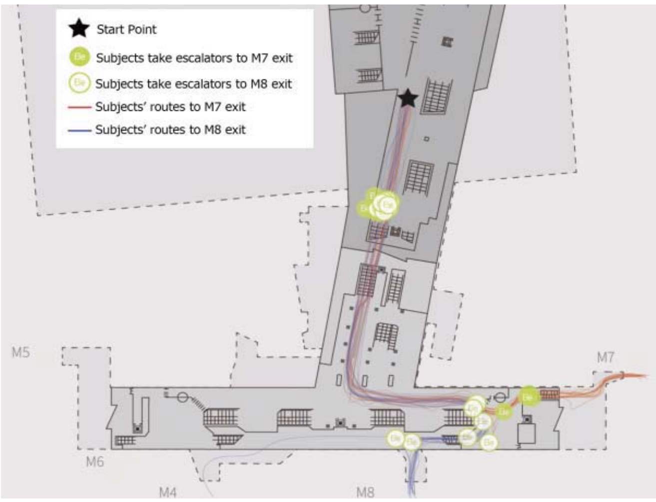

Fig. 13 Choosing the escalator for transitioning between floors

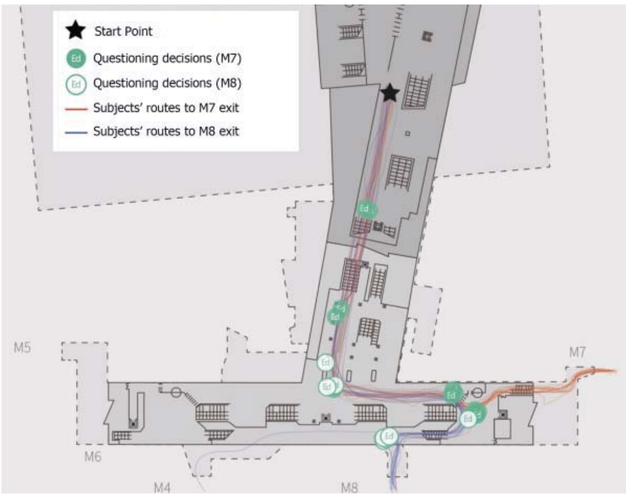

Fig. 14 Questioning decision

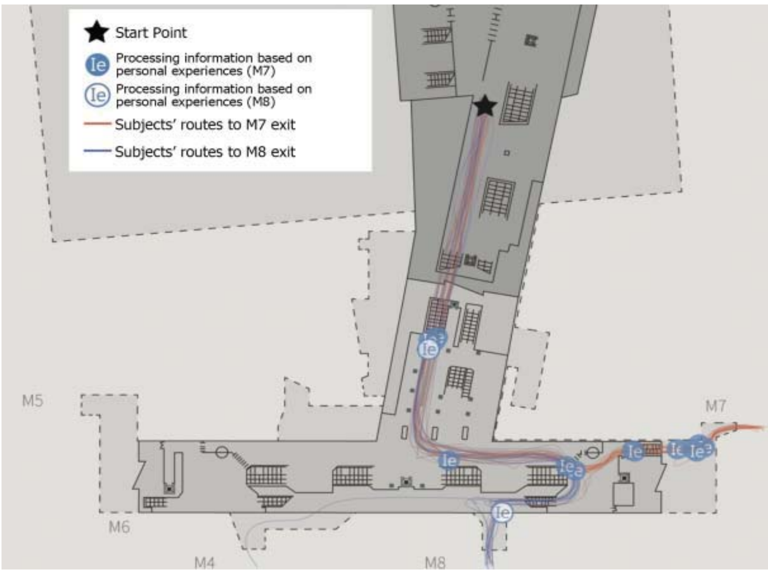

Fig. 15 Processing information based on personal experience

Fig. 16 Following a pathway

Participants using the evacuation interface resorted to their personal experiences when choosing evacuation routes. For example, when encountering the railings separating crowd flow at the transition point between B3 and B2, some members followed their own experience and chose either sides of the railings. Members assigned to the M7 exit drew from both their surroundings and personal experience to assess that M7 was ahead when transitioning from B1 to 1F.

Participants also used both the movement of the crowd and the route provided by the interface, reading the left turn icon on the mobile phone interface or turning with the crowd flow. For example, some members of the M7 group making the transition between B2 and B1 noted of the icon pointing to exit M7 in the surrounding environment, whereas some members of the M8 group followed the directions on the interface as well as considering the crowd flow and made a right turn upon exiting the station gate.

Interview results showed that most participants considered "turn icon of the evacuation route" as helpful for successful evacuation because it informed them where the turn was. Because most participants were attentive to the route on the map, most noted the turn icon when making the turn. Many participants considered the "floor transition icon" helpful for decision-making when they were about to transition between floors. The presentation was similar to that of the "present location icon," which reminded participants that the next segment of the route would include stairs. Additionally, most participants did not use "return to present location" or "compass" for evacuation purposes, and did not take note of these functions during the experiment. Some believed the "return to present location" icon had low understandability and ignored the function because they did not understand it. Others thought that the function could help lost users reorient themselves. The responses were thus split. Most members considered the compass to provide no critical assistance in an underground evacuation and therefore to be of low functionality.

Regarding facilities, most participants considered lavatories and elevators helpful for orientation. In particular, lavatories were commonly used facilities and could be easily recognized. However, lavatory indicators in the metro space are installed along walls, which could easily be obstructed by pillars or missed. The color, size, and anthropomorphic icon of the lavatory indicator could easily be confused with the elevator icon, which was also of sufficient size and attractive design to allow evacuees to recognize it and orient themselves. Some members mentioned that elevators would not be a means of evacuation in a fire emergency and therefore had relatively low functionality.

Most participants agreed that the design and placement of facilities icons helped participants orient themselves, but some facility icons should be prioritized to avoid confusion. Also, some participants considered the fire extinguisher symbol to be more important than other facility icons because it could be used to respond to fire emergencies. Unfortunately, most participants did not see the locations of the fire extinguishers in their surroundings. As for phone booths, their function could be easily replaced by a cellular phone, and evacuees may not see them during evacuation situations because of their relatively small size.

Most participants treated the target prompt as the priority when viewing push notifications from the navigation bar. They also cross-referenced the information provided in the navigation bar with the route on the map, and the text description offered them clarity to reconfirm their targets. The interface provided to participants comprised primarily two types of evacuation information, namely the map and navigation bar, and only a few participants focused on only one type of information. Most participants considered target exit information to be of relatively low importance in an evacuation because they would aim to leave the scene of the fire as quickly as possible. Therefore, most participants focused on the map and evacuation route, with over half of the members not noticing the icon or the text of the target exit on the navigation bar at all. Some only discovered that the navigation bar indicated the target exit after they had reached the exit. In sum, to meet the needs of a variety of users, this study recommends still providing the map and the navigation bar. Most participants noticed the "warning effect of the fire's point of origin," and considered this a vital feature that prevented them from moving toward the fire and therefore a critical component in the interface.

V. CONCLUSIONS

This study proposed a revised version of the interface design based on experiments, interviews, and feedback. The proposal focused on the functions and information provided by the interface. The color of the interface and the navigation bar remained unchanged. Other changes, six in total, are the following:

1) Notification Bar: Feedback from the interviews indicated that the participants paid less attention to the target entrance notification during the evacuation because of the urgency required to leave the scene of the fire as quickly as possible. The limited area and size of the text made it more likely for users to miss the notification or to be unsure whether it is the target exit. Therefore, this study optimized the presentation of the text by shortening the original text.
2) Spatial mapping: The map was in greyscale, with light grey designating accessible areas and dark grey for inaccessible areas. All floors were contoured to distinguish them. A study by Chiu on map wayfinding systems indicated that maps must present realistic and accurate representations of the surroundings to provide users with the proper means of orientation [2]. People use their vision and brains to process and project information from their surroundings into three-dimensional (3D) space. Pseudo-3D or "2.5D" mapping is apposite for human cognition and is conceptually similar to the "landmark" feedback from the study interviewees. Therefore, the proposed revision incorporated a 2.5D pseudo-3D mapping component.
3) Evacuation route: The revision retained the original colors and icons that indicated route, present location, and floor transition. Some modifications were made regarding the color of the turn icon positioned along turns on the route, both to avoid confusion with the map and other icons and to streamline the presentation of the main evacuation route.
4) Compass and "return to present location": Interviews indicated that the participants rarely used the compass function in underground spaces. The compass is an instrument of orientation that identifies absolute position, but participants showed a preference for instruments that could provide relative orientation. Therefore, the revision deleted the compass function from the interface design. Also, the "return to present location" function was considered by the participants to be a useful navigational function that could help them identify their present location. For this reason, the "return to present location" function was preserved but modified into a more universal design.
5) Facilities icon: The original design of the interface displayed icons of infrastructural installations such as lavatories, elevators, and telephone booths, to provide users with relative positioning information that could contribute to their evacuation. However, the interviews revealed that the participants easily misunderstood the purpose of the icons, which did not help them evacuate effectively. Nevertheless, the participants suggested that the lavatory and elevator icons be enlarged because they could be used for identifying their relative position. With

these in mind, the revision incorporated the 2.5D mapping component, which used larger infrastructural installation icons with realistic spatial projections within the map, thereby increasing the spatial recognition ability for users. Reducing the number of icons in the map could also lower the degree of complexity of the interface so that users could focus on the evacuation itself. Most participants thought that the location of fire extinguishers should be the most critical information in a fire; therefore, the revised proposal emphasized the fire extinguisher icon to distinguish it from the evacuation map.

6) Fire's point of origin notification: The feedback from most participants in the interviews indicated that the point of origin of the fire was critical information for evacuation purposes. However, some contended that the previous design of the point of origin icon was poorly defined, leading to the misconception that it was merely a visual effect. The revision included interface design modifications to clarify the icon's function as an indicator of the fire's location. The new design is a flame graphic that indicated the origin of the fire with the intention of presenting a clear warning signal to evacuees.

Fig. 17 Revised interface design proposal

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