An Experimental Study on Dynamic Signage for Autonomous Evacuation Navigation System: The Effectiveness through User's Perception

Khyrina, Airin Fariza Abu Samah; Burairah, Hussin; Abd Samad, Hasan Basari

***Abstract*—** Current existing static signage system (SSS) used to guide the occupant's wayfinding to the nearby main exit. Yet, it does not navigate to the safest and shortest route direction. This situation has led the evacuation process become more critical and challenging, especially when they were getting into traps at the spreading hazardous location. Thus, a dynamic signage system (DSS) in the autonomous evacuation navigation system (AENS) is proposed to overcome this problem. Through the system, it will block the hazardous area, provide the safe route information and navigate the occupants to the nearest exit. The effectiveness were verified and evaluated via 6 sets of experiments using SSS and DSS in two different floor plan layout. There were 30 participants involved and run the specific experiment, which consists of 2 groups of occupants; 10 familiar and 20 unfamiliar. After the completion of the experiment, they were required to fill-up a set of survey regarding their understanding and satisfaction of the proposed system. The result obtained shows a difference significant on the time taken to the nearest staircase, between familiar and unfamiliar occupants. Nonetheless, all the participants showed a 100% satisfaction towards the effectiveness of DSS implemented in the AENS.

***Keywords*—**Autonomous evacuation navigation system, dynamic signage, safest and shortest, static signage, unfamiliar wayfinding, navigation.

I. INTRODUCTION

THIS present in Malaysia, all the building are complied with the standard regulations in the National Fire Protection Association (NFPA) codes and standards, Fire Services Act 1988, Uniform Building By-Law (UBBL) 1984, and Hazardous Material (HAZMAT), as the a fire safety standards. Its main objective of fire safety is to provide the occupants' safety in enclosed environments, avoiding, reducing the number of fatalities, the number of injuries, and any death cases [1], [2]. In addition, Occupational Safety and Health Administration (OSHA) Act of 1970 also provides guidance for emergency standards for employers and employees to reduce on the job injuries, illnesses and deaths.

Signage system is one of the standard fire safety codes implemented in the building. The signage systems are one of the important and widely used as wayfinding information. It was designed with the specific installation guideline such as the size, height, design, position, location of the sign, specific distance, and etc. The standard signage used in most of the buildings using symbol only, or wording only or combination of both the symbol and wording. It reacts as an agent to convey the wayfinding information and assisting occupants towards to the exit. An effective signage system can reduce the apparent complexity of an enclosure thereby improving wayfinding under both general circulation and emergency conditions. On the other hand, ineffective signage may contribute to the loss of commercial earnings in general circulation situations, which has more serious consequences in emergency situations [3].

In this research, we were focusing on exit signage usage for exit navigation guidance during the emergency evacuation. There are two types of character in signage system; static and dynamic. The traditional signage was considered as static signage system (SSS), for example the exit signage and emergency building floor plan system (BFPS) as shown in Fig.1 and Fig.2. Both are the common signage systems designed, and used in most of the building. Normally, it's made of a metal or plastic, which react as a passive communication and constant due unable to update automatically in real time changes. In contradict dynamic means energetic, capable of action and able to adapt real time changes. The dynamic sign system (DSS) usually uses advanced technology, and able to switch attention and break into consciousness when attention had been focused on other tasks.

Wayfinding during emergency evacuation is a challenging issue and critical problem, especially for those unfamiliar occupants [4]. It may vary depending on human behavior, knowledge, experience and the building environment. Despites the SSS is intended to help overcome the wayfinding problem, in real situations when the hazardous spreads and

This research project is conducted by Universiti Teknikal Malaysia Melaka, Malaysia (UTeM) which funded from Malaysian government under the Fundamental Research Grant Scheme (FRGS/1/2013/ICT07/02/2/F00162 - A New of Independent Evacuation Preparedness Algorithm for Critical Incident).

Khyrina A.F.A.S is with the Faculty Information Technology and Communication, Universiti Teknikal Malaysia Melaka, 76100 Durian Tunggal, Melaka, Malaysia (phone: +606-331-6534; fax: +606-331-6500; e-mail: rinarinza@gmail.com).

Burairah H. is with the Faculty Information Technology and Communication, Universiti Teknikal Malaysia Melaka, Malaysia (phone: +606-331-6534; fax: +606-331-6500; e-mail: burairah@utem.edu.my).

Abd Samad H.B is with the Faculty Information Technology and Communication, Universiti Teknikal Malaysia Melaka, Malaysia (phone: +606-331-6536; fax: +606-331-6500; e-mail: abdsamad@utem.edu.my).

block the directed exit area, it failed to navigate towards the safest location. In addition, with the SSS design, it can only point to the nearest exit [5], which occupants have less information on the safe path to follow, especially for those unfamiliar occupants. Also, the deficiency problem of information conveyed by the emergency SSS caused the less effectiveness of its main purpose [6].

Fig.1: Example of exit sign for emergency egress

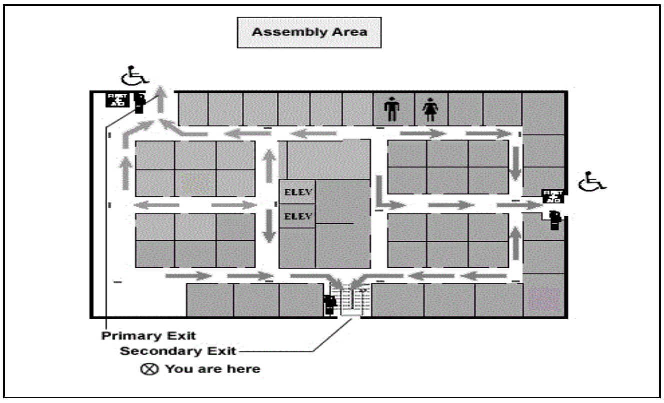

Fig.2: Emergency building floor plan system (BFPS)

According to [7]–[10], it was proven the occupants used the familiar path as the exit selection (the path used when they entered the building), become as followers or reacts as agents to lead the emergency evacuation, tend to follow light, withdraw to previous location when encountered fire or smoke, and follow the spacious environment compared to many obstacles. These also been supported through study by [6], only 38% of the participants see the present of static signage, and concluded the traditional static emergency signs are no longer effective due to possibilities of the collision and other unexpected problem, especially in a complex building. Although a mathematical approach was presented, the complexity of human actions makes it unfeasible [11], due to differences behavior in real situation of emergency as cited by Yuan (2005) in [12].

A successful wayfinding design allows people to determine their location within a setting, determine their destination, and develop a plan to take them from their location to the destination [13], [14]. In order to overcome the gap, we study the importance of providing information through dynamic signage. As claimed by [15], the understanding, use of the information, and the cognitive processes towards signage is more important compared to the sign visibility conditions and design. Therefore, we proposed an autonomous evacuation navigation system (AENS), the evacuation preparedness awareness solution to help occupants in wayfinding navigation during the emergency evacuation. In AENS, we implemented DSS which consists of specific function of navigation sign.

Hence, this paper was organized as follows: section 1 discuss on the background of problem; section 2 explained the systems thinking adaptation in AENS and the AENS function; section 3 focusing on the experimental methodology used – the objectives and hypothesis, and the specific method used; section 4 discussed the result based on the observation, comparison of arrival time, and the participant's satisfaction; and section 6 provides a brief conclusion of our work and future work

II. Conceptual Framework for AENS

A. *Systems Thinking Adaptation in AENS*

Systems Thinking (ST) is conceptual framework, which analyzed and answered the basic of 5W 1H questions, "what, where, why, when, who and how", and then proceed with solution finding. The full patterns of system behavior can be clearer identified due to each of the systems is interrelated and any changes of the process can be seen clearly, instead of discrete snapshots [16]. Most of the problems were viewed and solved from various perspectives, depending on human knowledge and experience. Applied ST comes into place because the need to change the mindset, addressing the problem and manage uncertainty, risk, priority, and opportunity. Moreover, in order to understand the relationship and interaction for requirement of the proposed solution, it reframed the problem through an expanded view and followed by evaluating the potential outcomes, and its rationality in overcoming the problem.

B. *Explanation on AENS Functions*

The AENS was developed from the integration of the involved in designing the navigation system which might help occupants to find the safest and shortest route to exit. We integrated the systems involved starting from the detection until the evacuation into one coherent system linked the components in order to achieve its purpose and mission. Through the system integration (SI) for AENS, we use our existing system capability and resources, to avoid the complexity problem and high cost incurred.

This evacuation preparedness model, AENS was proposed to overcome the wayfinding problem, especially for unfamiliar occupants [17]. Fig.3 shows the conceptual framework of SI for AENS, which starts from the adaptation of systems thinking (ST) to the existing subsystem. ST changes the system behavior into a system point of view and studies the connection between sub-systems. ST adapted human, integrated to be as a part of the system and they need to follow the instruction of the emergency evacuation.

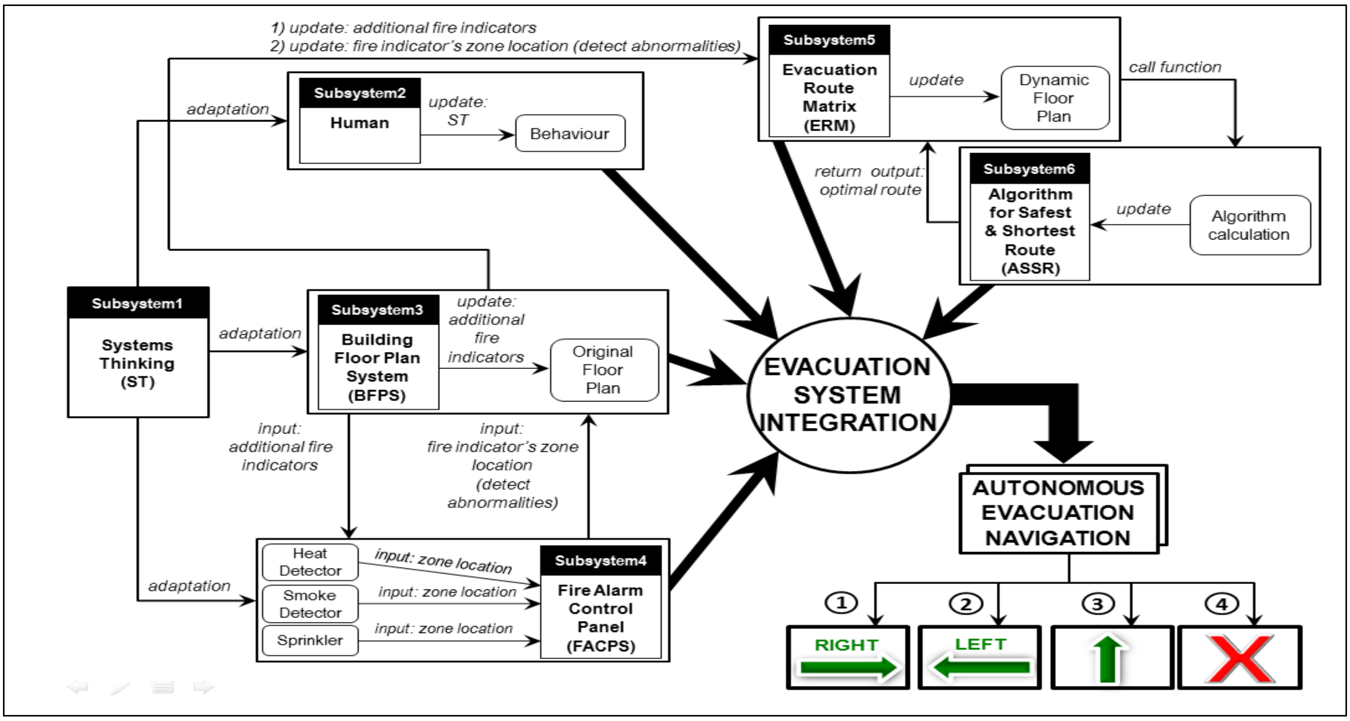

Fig.3: Conceptual Framework: System Integration for Autonomous Evacuation Navigation System

Table 1: Dynamic Signage System (DSS) in AENS

Signage	Interpretation	Signage	Interpretation
	Direction to follow the right path		Direction to follow the left path
	Direction to follow the straight path		Direction not to entered the path

The ST concepts also been adapted in the fire alarm control panel system (FACPS), and building floor plan system (BFPS). Both, FACPS and BFPS must be integrated, so BFPS knows the location of hazardous. With the proactive fire indicator in FACPS, it will trigger siren for emergency evacuation and send the involved fire indicator's location information to BFPS. Once BFPS received it, automatic the floor plan is updated and sends the latest updated information to the evacuation route matrix (ERM). ERM stored information of the floor plan layout with the specific fire indicator's location. ERM called another subsystem, algorithm for the safest and shortest route (ASSR) to perform a calculation for the safest and shortest route using a specific algorithm. Each of the subsystems plays an important role to ensure the accurate information given to AENS towards to the safest and shortest route. At the end, once the AENS received the "optimal route" information, it provides 4 types of DSS; 1) right, 2) left, 3) straight and 4) no entry (cross mark). The DSS is available at the sub exit of the main door in specific zone area. Table 1 explained further the specific function of the DSS in AENS, which should appear during the emergency evacuation of fire and its interpretation.

III. Experimental Methodology

A. Objectives and Hypothesis

The experiments were designed to evaluate the effectiveness of the DSS used and implemented in the AENS, which will display the navigation through a specific signage. Therefore, we set the specific objectives and hypothesis to measure and validate the experiments. The objectives as below:

1) To compare the time taken to reach the nearest safe exit for unfamiliar occupants with the SSS with the dynamic signage system DSS;
2) To evaluate the level of understanding towards the dynamic signage;
3) To examine is there any adverse effect of the DSS, such as causing confusion and hesitation.

Hence, the hypotheses are concerned at the experimental time taken results are:

H_0: There is no difference in the experimental time taken result between SSS and DSS, and

H_1: There is a difference in the experimental time taken result between SSS and DSS.

B. Building and Participants

The experiments were conducted at the level 13th and 14th of the office building as illustrated in Fig.4 with legends of the main entrance, left staircase exit and right staircase exit. This building was selected due the complex and using close building concepts, and commonly visited by unfamiliar occupants.

There are 30 unfamiliar participants, 10 familiar and 20 unfamiliar occupants, in which the experiments consist of eight sessions:

1) Experiment 1 (E1): Level 13-unfamiliar occupants evacuate using the SSS,
2) Experiment 2 (E2): Level 13-unfamiliar occupants evacuate using the DSS,
3) Experiment 3 (E3): Level 14-unfamiliar occupants evacuate using the SSS,
4) Experiment 4 (E4): Level 14-unfamiliar occupants evacuate using the DSS,
5) Experiment 5 (E5): Level 13-familiar occupants evacuate using the SSS,
6) Experiment 6 (E6): Level 13-familiar occupants evacuate using the DSS
7) Experiment 7 (E7): Level 14-familiar occupants evacuate using the SSS, and
8) Experiment 8 (E8): Level 14-familiar occupants evacuate using the DSS

The participants came from different gender, level of age and education. Before the experiment starts, we conducted a short briefing, in order to ensure the smoothness of the activity. The participants were reminded that the experiment is not the competition, so they need to react as normal behavior. The souvenir and certificate were given out after the completion of the experimental and survey.

C. Procedures for SSS

The SSS evacuation procedure as below:

1) Certain areas will be blocked by fire (placing cones and hanging rope with pictures of fire).
2) Each experiment involved 5 unfamiliar/familiar occupants searching for wayfinding to exit.
3) At start time, $t_s = 0$, all the participants allocated randomly in the office, according to the specific zone location as shown in Fig.5 (number in yellow and red circle).
4) All of them wore the specific tag with identification (ID) number and color to differentiate the group.
5) The evacuation started as soon as the emergency alarm was given out.
6) The participants evacuate, follow the SSS or any path to exit.
7) Once they arrived at the nearby staircase, we recorded their arrival (end) time, t_e.

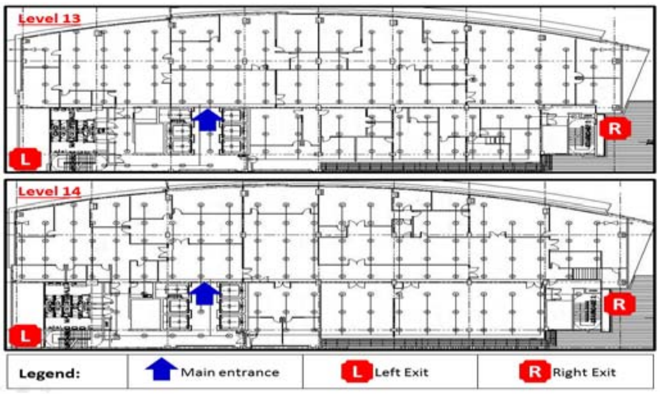

Fig. 4: Experimental floors plans layout – Level 13th and 14th of Yayasan Melaka

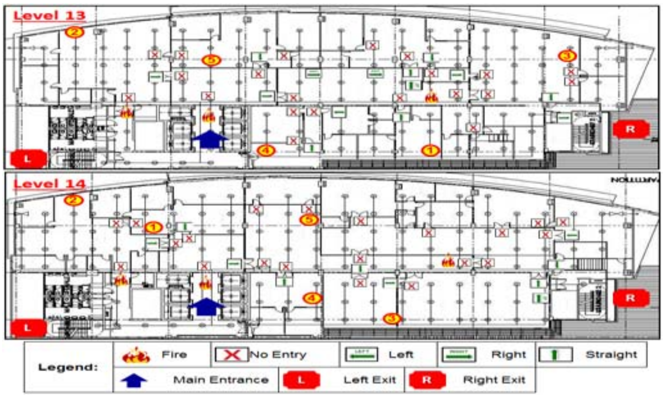

Fig. 5: Unfamiliar participant's location and DSS in AENS during the experiment

D. Procedures for DSS

The DSS evacuation procedure as below:

1) Certain areas will be blocked by fire (placing cones and hanging rope with pictures of fire).
2) Each experiment involved 5 unfamiliar/familiar occupants searching for wayfinding to exit.

3) At start time, $t_s = 0$, all the participants allocated randomly in the office, according to the specific zone location.
4) All of them wore the specific tag with identification (ID) number and color to differentiate the group.
5) The evacuation started as soon as the emergency alarm was given out.
6) The participants evacuate, and need to follow the DSS. The dynamic DSS in AENS consists of right arrow, left arrow, straight arrow and no entry.
7) Once they arrived at the nearby staircase, we recorded their arrival (end) time, t_e.

E. Measurement

In this section, the measurement was divided into two parts; 1) the arrival time taken from the allocated location until they reach the nearby staircase; and 2) the outcome result from the survey form.

The arrival time for individual participants were recorded manually by two helpers. The first helper stops the stopwatch once the participants reach the exit door. The second helper gave a card with an ascending number to all the participants based on first come first serve basis. It was purposely to know the arrival position of the participants. Then, they will record the time taken together with the arrival number.

After completing the experiment, all the participants being asked to complete a survey related to the experiment and system. The survey questionnaire included items that address the constructs included in the proposed model, including user satisfaction. Since the survey was conducted in government office, the measurement that was originally written in English was translated into Bahasa Malaysia. It starts with the brief information about the research, then on the first section, the five statements about the demographic characteristics inclusive the experience in any emergency evacuation.

On the second section, we accessed the user satisfaction towards their experience during the experiment. The six statements were rated on a 5-point scale (5=very satisfied, 4=satisfied, 3=neutral, 2=not satisfied, and 1=very dissatisfied) and one open-ended item. The statements included: 1) I understand the purpose of the system development; 2) the system is easy to follow; 3) The system is easy to understand; 4) The system helpful to guide me to the safest exit; 5) I would recommend the system to others; and 6) Overall, I am satisfied with the new system. The seventh question used open-ended item, so users have the opportunity to comment about the system.

On the last section, we accessed six questionnaires regarding the user understanding on the AENS dynamic signage used using open-ended item. Prior to administering the experiment and survey, the Fire and Rescue Department of Malaysia examined the experiment and the survey administration protocol. During the submission of the survey form, the helpers check it to ensure all questionnaires completed by the participants.

IV. Results and Discussion

In order to ensure that all objectives are answered, the results and discussion section was divided into five parts; 1)participant's demographic information, 2)experimental observation, 3)comparison of the arrival time, 4)participant's satisfaction, and 5)findings from the objectives and hypothesis.

A. Participant's Demographic Information

As in Table 2, the data obtained from the 10 familiar and 20 unfamiliar participants; 50% are male and female, and with the range age from 20 years old to 45 years old. 75% of them have experience in fire drill, 25% never have any experience and none has experience in the real fire. Age fraction of the participants showed a different purpose for entering the building. For example, 50% of unfamiliar participants were interested to know more about education loans provided by the office. It is consistent with the fraction of 40% is the participants who have certificates and diplomas.

Table 2: Demographic information of the respondents ($n = 30$)

Status	n	%	Education	n	%
Familiar	10	33.3%	SPM	5	16.7%
Unfamiliar	20	66.7%	Certificate	6	20.0%
			Diploma	5	16.7%
Gender	**n**	**%**	Bachelor Degree	11	36.7%
Male	15	50%	Master	3	10.0%
Female	15	50%	PhD	0	0%
Age	**n**	**%**	**Experience in Evacuation**	**n**	**%**
< 20	0	0%	Fire Drill	23	76.7%
20 - 25	11	36.7%	Real Evacuation	1	3.3%
26 - 30	11	36.7%	Never	6	20%
31 - 35	2	6.7%			
36 - 40	3	10.0%			
41 - 45	3	10.0%			
46 - 50	0	0%			
> 50	0	0%			

B. Experimental Observation

Unfamiliar: Level 13th - During the experiment 1 (E1) for SSS, the participant with ID 1, 2, 4 and 5 were trying to find a way out by using room to room technique, once they found out the main entrance and alternative door with SSS have been blocked by fire. They also discussed among themselves and withdraw to previous location until the participant ID 1 found the way to exit, called the others and finally reach the nearby staircase. In experiment 2 (E2) for DSS, the participants smoothly follow the signage provided and once they saw the participant ID 1 passing the route to the exit, they just follow until reach the nearby staircase.

Unfamiliar: Level 14th - The similar scenario as E1 observed during the experiment 3 (E3) for SSS, but due to the floor plan layout was not complex as in level 13th, the movement is smoother. Level 14th layout was more open, less "room in the room" concept, and easy to predict the alternative route. Participant ID 3 was the first person found the exit route, after withdrawals from the opposite room and followed by others. During the experiment 4 (E4) for DSS, the participants smoothly follow the DSS provided and reach the nearby staircase safely, exactly the same observation in E2.

Familiar: Level 13th - During the experiment 5 (E5) for SSS, all the participants directly follow their familiar route, once they found out the main entrance and alternative door with SSS have been blocked by fire. They able to find out the alternative route since they are familiar with the floor plan layout. The evacuation process during experiment 6 (E6) able to minimize the duration time taken because the participants follow the signage provided and they know the alternative route available.

Familiar: Level 14th - The similar scenario as E5 and E6 been observed during the experiment 7 (E7) for SSS and experiment 8 (E8) for DSS. Due to the open layout, they easily predicted the alternative route.

C. Comparison of the Arrival Time

Fig. 6 and Fig. 7 illustrates the evacuation result of E1 vs E2, and E3 vs E4 on the comparison of the arrival time taken for unfamiliar participants to the nearby staircase, between SSS and DSS for level 13th and 14th. Based on Figure 6, the participant with ID 3 in level 13th recorded the small difference of the arrival time compared to others due the location was nearby the staircase exit and did not face any obstacles of the fire hazard. On the other hand, the participant with other ID 1 took longer time to arrive because need to go through all areas during the wayfinding. During the experiment, the arrival time for occupant ID 1, ID 2, ID 4 and ID 5 shows more or less the same figure. As mentioned during the observation, they discuss among themselves trying to find a way out. In overall, we noticed that the evacuation process completes faster when we implemented the DSS in AENS with an average of 77 % and 45% of improvement in level 13th and 14th.

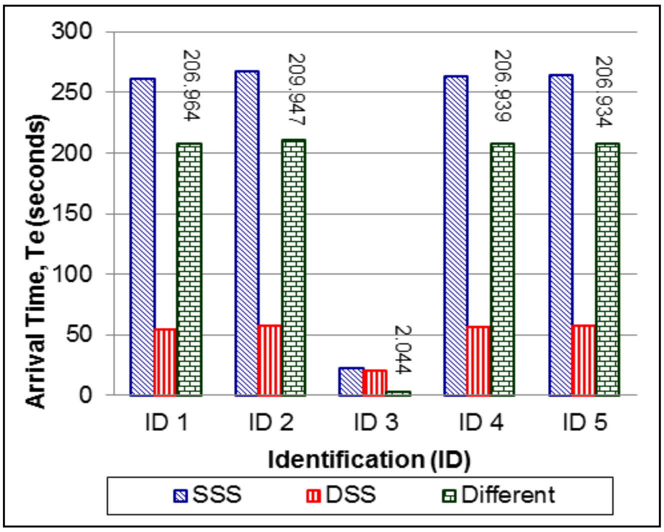

Fig. 6: Comparison of unfamiliar occupants' arrival time between SSS and DSS at level 13th (E1 vs E2)

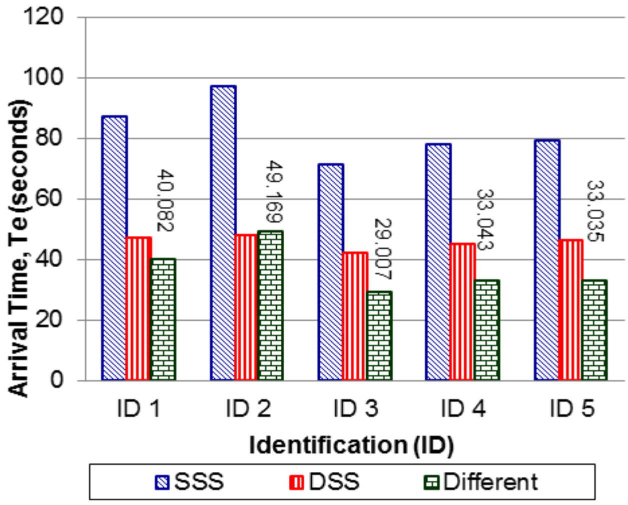

Fig. 7: Comparison of unfamiliar occupants' arrival time between SSS and DSS at level 14th (E3 vs E4)

Fig. 8 and Fig. 9 shows the result of E5 vs E6, and E7 vs E8 on the comparison of the arrival time taken of the familiar participants to evacuate to the nearby staircase, between SSS and DSS for level 13th and 14th. Despite they are familiar; the evacuation time taken is faster when DSS is implemented with 10% and 18% of improvement in level 13th and 14th.

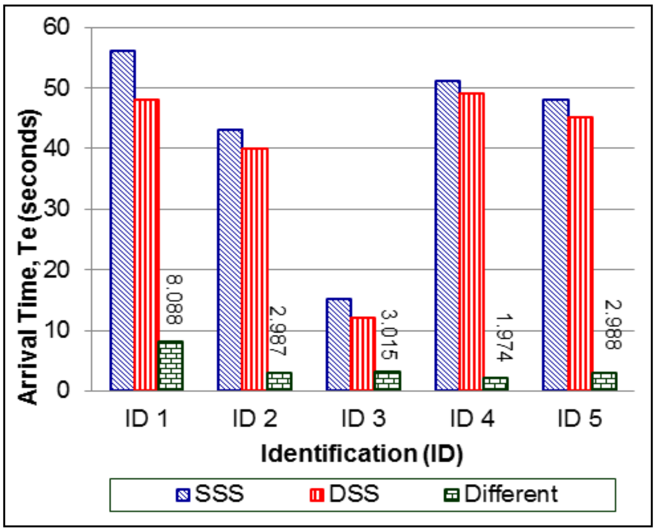

Fig. 8: Comparison of unfamiliar occupants' arrival time between SSS and DSS at level 13th (E5 vs E6)

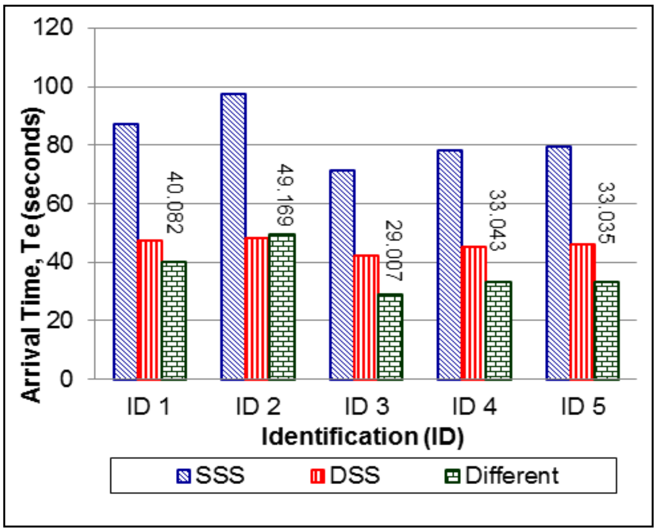

Fig. 9: Comparison of unfamiliar occupants' arrival time between SSS and DSS at level 14th (E7 vs E8)

D. Participant's Satisfaction

Fig. 10 shows the participant's satisfactory results after analyzing the survey given once completes the experiment. Majority of them voted for satisfied and very satisfied answer. Question 1 (I understand the purpose of the system development) showed 56.67% satisfied and 43.33% of very satisfied. Question 2 (the system is easy to follow) achieved balance results of 50% for both answer. Question 3 until 5 (the system is easy to understand, the system helpful to guide me to the safest exit, I would recommend the system to others) showed the same result; 46.67% of the participant was satisfied and 53.33% were very satisfied. Highest satisfaction of 56.67% was voted by a majority of the participants when answering question number 6 (overall I am satisfied with the new system) and 43.33% very satisfied.

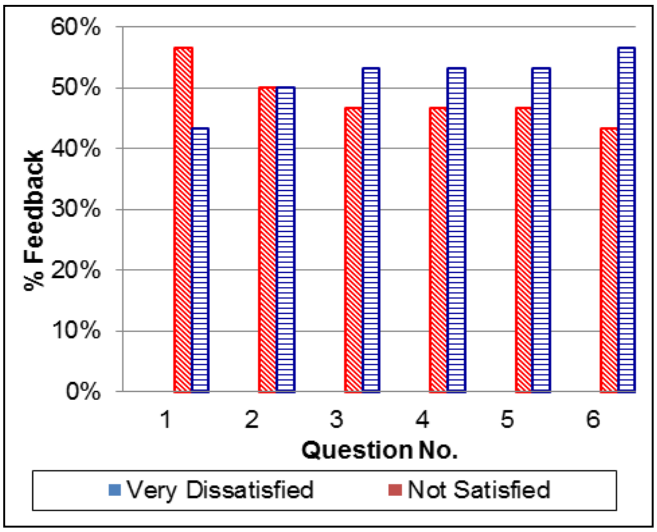

Fig. 10: Participants satisfaction towards the DSS in AENS

For unfamiliar occupants, we received several good comments for question number seventh, such as, *"good"*, *"an effective exercise"*, *"the buildings must have wayfinding signage to exit as provided in this exercise"*, *"this system easy to understand"*, *"good! this system is easy to understand"*, *"ok, good, "can be practiced at other multilevel building"*, *"good in terms of preparation if real things happened"*, *"new system needed to increase the effectiveness of the current system from time to time. The systems need to communicate to make it more practical. Well done!"*, *"this system is very helpful in terms of route signs"*, *"clear objectives and an organized system and straight forward"*.

On the other hand, for familiar occupants, they also give the good comments, such as, *"good"*, *overall good system"*, *"use the real material such as fire or smokes for the experiment"*, *"staff do not need the signage but the signage makes us feel confident and safe"*. The last question accessed on the user understanding related to the DSS used in AENS during the experiment and achieved 100% the correct answer for the signage used.

E. Findings from the Objectives and Hyphothesis

We applied inferential analysis, the Mann-Whitney U test with continuity correction in order to further find out whether the differences between the results are statistically significant. The test is only focusing for unfamiliar occupants to study the effectiveness of the experiment. As mentioned before, the null and alternative hypotheses to the test are; H_0: There is no difference in the experimental time taken result between SSS and DSS, and H_1: There is a difference in the experimental time taken result between SSS and DSS.

Based on the test result as shown in Table 3, the two-tailed *p-value* for both levels is 0.027 and 0.001; which *p-value* < 0.05. Therefore, we rejected the H_0 with this sufficient evidence, significant (*p-value<0.05) and support our H_1 that there is a difference in the experimental time taken result between SSS and DSS.

Table 3: Mann-Whitney U test of Two-Sample

	Level 13		***Level 14***	
	SSS	***DSS***	***SSS***	***DSS***
Min	22.070	20.030	71.100	42.090
Max	267.030	57.090	97.171	48.000
Median	263.010	56.070	79.120	46.090
Mean	215.435	48.869	82.534	45.667
var	1688.790	261.425	99.468	5.205
p-value	**0.027**		**0.001**	
***p<0.05**				

In previous section, we have set the objectives and hypothesis. Overall, we founded that we have already achieved the targeted objectives and the accepted hypothesis as shown in Table 4.

Table 4: Summary of Objectives and Hypothesis

Measurement	Results and Findings
1. Compare time taken within SSS and DSS	Time taken using DSS < time taken using SSS
2. Understanding level towards DSS	Very satisfied : 56.67% Satisfied : 43.33%
3. Adverse DSS effect (confuse/hesitation)	100% answered the correct interpretation
4. Hypothesis for unfamiliar	*p-value* = 0.027 and 0.001*;* (Rejected H_o)

V. CONCLUSION

Our main focus is to ensure occupants able to evacuation independently without any agents help towards the safest and shortest nearby exit, potentially for unfamiliar occupants. Through the experimental results, founded and strong support that the time taken were reduce when we tested using DSS in AENS. The two-tailed p-value 0.027 and 0.001 also has proven its effectiveness to overcome the wayfinding problem with the combination of system integration. In addition, participant's also claimed 56.67% of them were really satisfied with the new system.

We will continue our efforts to extend the indoor wayfinding research to further types of public buildings with different spatial layouts and properties. This study is predicted successful if human become as a subsystem and give full cooperation, nevertheless, the enhancement is needed on the policy enforcement. Besides, as claimed by [18], evacuation data are generally affected by behavioral uncertainty, and a single experiment may not be representative of a full range of the behaviors of the occupants.

REFERENCES

[1] R. M. Tavares, "Design For Horizontal Escape In Buildings: The Use of The Relative Distance Between Exits as An Alternative Approach to The Maximum Travel Distance," *Saf. Sci.*, vol. 48, no. 10, pp. 1242–1247, Dec. 2010.

[2] Z. Jiang, P. Zhang, R. Shang, and X. Tian, "Investigation and Simulation on Human Evacuation Behaviour in Large Hospital Building in Shenyang," *Procedia Eng.*, vol. 71, pp. 101–106, 2014.

[3] L. Filippidis, P. Lawrence, E. Galea, and D. Blackshields, "Simulating the Interaction of Occupants with Signage Systems," in *Proceedings of the Ninth International Symposium in Fire Safety Science*, 2008, vol. 9, pp. 389–400.

[4] K. A. F. A. Samah, B. Hussin, and A. S. H. Basari, "The Effectiveness of Dynamic Signage for Autonomous Evacuation Navigation System : An Experimental Study 2 Conceptual Framework for AENS," in *3rd International Conference On Circuits, Systems, Communications, Computers And Applications (CSCCA '14)*, 2014, pp. 1–9.

[5] J. Lindström, L. Barna, P. Stevn, and R. Eggleton, "Human Guiding , Turning Theory into Practice," in *Pedestrian and Evacuation Dynamics*, 2011, pp. 837–841.

[6] H. Xie, E. R. Galea, and P. J. Lawrence, "Experimental Study of The Effectiveness of Dynamic Signage System," in *13th International Conference Proceedings in Fire Science & Engineering*, 2013, pp. 967–978.

[7] R. Engineering, "Timing Human Response in Real Fires," in *Proceeding of the Fifth International Symposium in Fire Safety Science*, 1997, pp. 807–818.

[8] S. Gwynne, E. R. Galea, P. J. Lawrence, and L. Filippidis, "Modelling Occupant Interaction With Fire Conditions Using the BuildingEXODUS Evacuation Model," *Fire Saf. J.*, vol. 36, pp. 327–357, 2001.

[9] P. Shuangyun, Y. Kun, X. Quanli, and H. Yuhua, "The Simulation Research on the Evacuation Model of Supermarket by Using GIS and Agent-Based Modeling Technology," in *International Symposium on Intelligence Information Processing and Trusted Computing(IPTC)*, 2010, pp. 499–502.

[10] K. A. F. A. Samah, B. Hussin, and A. S. H. Basari, "A Systems Thinking in Natural Disaster Management : Evacuation Preparedness," in *Proceedings of the 1st WSEAS Advances in Economics, Risk Management, Political and Law Science*, 2012, pp. 384–389.

[11] M. H. Zaharia, F. Leon, C. Pal, and G. Pagu, "Agent-Based Simulation of Crowd Evacuation Behavior," in *Proceedings of the 11th WSEAS International Conference on Automatic Control, Modelling and Simulation Agent-Based*, 2009, pp. 529–533.

[12] S. Afandizadeh, A. Jahangiri, and N. Kalantari, "Determination of the Optimal Network Configuration for Emergency Evacuation By Simulated Annealing Algorithm," in *Proceeding of Environmental Science and Sustainability*, 2009, pp. 65–71.

[13] R. W. Giuliani and Mayor, *Universal Design New York*. 2001.

[14] C. Hölscher, S. J. Büchner, T. Meilinger, and G. Strube, "Map Use and Wayfinding Strategies in a Multi-building Ensemble," in *Spatial Cognition V Reasoning, Action, Interaction*, 2007, pp. 365–380.

[15] H. Xie, "Investigation into the Interaction of People with Signage Systems and Its Implementation Within Evacuation Models," Ph.D. University of Greenwich, 2011.

[16] P. M. Senge, "The Fifth Discipline - The Art and Practice of the Learning Organization," *Random House Digital, Inc.*, pp. 1–20, 2006.

[17] K. A. F. A. Samah, B. Hussin, and A. S. H. Basari, "A Robust System Integration for Autonomous Evacuation Navigation," in *13th International Conference on Intelligent Software Methodologiew, Tools and Techniques*, 2014, pp. 692 – 702.

[18] K. Fridolf, E. Ronchi, D. Nilsson, and H. Frantzich, "Movement Speed and Exit Choice in Smoke-filled Rail Tunnels," *Fire Saf. J.*, vol. 59, pp. 8–21, 2013.

Khyrina Airin Fariza Abu Samah received a Diploma in Computer Science from Institute which is now known as University Technology Mara (1997), B. IT and Management (Hons.) in 2007 and M.Sc. Computer (Software Engineering and Intelligence) from the University Technical Malaysia Melaka (2010) and pursuing Ph.D. Emerging in Algorithms and Techniques in Technical University under the sponsorship of University Technology Mara. Her research interest includes Artificial Intelligence, System Intelligence and Software Engineering.

Burairah Hussin received his B.Sc. in Computer Science from University Technology Malaysia (1996), M.Sc. in dalam Numerical Analysis from the University of Dundee, Scotland (1998) and Ph.D. in Management Science at the Center for Operations Research and Applied Statistics (CORAS), University of Salford, UK. (2007). He is Associate Professor and currently the Manager C-ACT, Faculty of Information and Communication Technology at the Technical University of Malaysia Melaka (UTeM). His main research in operations research and artificial intelligence, but he has the expertise and experience in the application of technology to improve the quality of teaching learning, such as e-learning and web 2.0 technology.

Dr. Abd. Samad Hasan Basari received his B.Sc. in Mathematics from University National Malaysia (1998), M.Sc. in IT-Education from the University Technology Malaysia (2002) and Ph.D. in ICT from University Technical Malaysia Melaka (2009). His main research in Decision Support Technology, Modelling and Intelligent System.