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ACTIVE DYNAMIC SIGNAGE SYSTEM: A FULL-SCALE EVACUATION TRIAL

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ABSTRACT

Efficient evacuation from transport terminals in an emergency can be constrained by the complex nature of the buildings. Although emergency signage systems are widely used as a well-established means of facilitating evacuation, recent research demonstrates that only 38% of people ‘see’ conventional static emergency signage in simulated emergency situations. Besides, conventional signage only conveys single and passive information; therefore, they cannot be adapted to respond to developing evacuation situations. The EU FP7 GETWAY project addresses this problem for transport terminals through the development of an Intelligent Active Dynamic Signage System (IADSS), which routes terminal passengers to their optimal exit according to the distribution of occupants and the nature of the evolving incident. This paper presents the results of two full scale evacuation trials conducted in a rail station to establish the specific benefits of the Active Dynamic Signage System (i.e. ADSS, a subsystem of the IADSS without the intelligent component) over the current standard emergency signage system. These trials demonstrate that the flashing lights of the ADSS do have a greater effect on route choice compared to the standard signage system and therefore are more likely to promote the adoption of emergency evacuation procedures than would otherwise be the case, especially where evacuees are required to adopt routes not entirely based on proximity.

INTRODUCTION

Efficient evacuation from transport terminals in an emergency is usually constrained by the complex nature of the buildings. People often attempt to evacuate via the way they entered, bypassing or ignoring emergency exits, due to a lack of detailed knowledge of the geometry and situational information[1-3]. While staff may help manage an evacuation, they cannot be everywhere and they may not be able to correctly adapt their advice in a rapidly changing fire situation. Escape route signs are also widely used to convey wayfinding information to the evacuating population in complex buildings. However, recent research shows that only 38% of people ‘see’ conventional static escape route signs in simulated emergency situations in an unfamiliar building environment, even if the sign is located directly in front of them and their vision is unobstructed[4]. Furthermore, conventional escape route signs convey single and passive information and as such they cannot be adapted to respond to developing evacuation situations. These limitations in conventional signage systems have contributed to the loss of life in serious fires such as the Kings Cross Underground Station (1988), Düsseldorf airport (1996) and Daegu Jungangno station (2003) fires[5].

The EU FP7 GETWAY project[6] aims to address the highlighted deficiencies in conventional signage systems through the development of an Intelligent Active Dynamic Signage System (IADSS), which will direct building occupants to the optimal exit during an evolving incident. The IADSS consists of an intelligent evacuation strategy selection support system and an enhanced signage system, the Active Dynamic Signage System (ADSS). The intelligent component of the IADSS makes use of environmental situational information collected through the fire detection system and the actual population distribution collected through the CCTV system and feeds this information to a faster than real-time evacuation simulation performed by the buildingEXODUS software[7]. The buildingEXODUS software runs through all the possible evacuation scenarios and passes the results to the Decision Engine which then automatically ranks the evacuation scenarios from best to worst. The information is then passed onto the human controller who finally decides on the most appropriate evacuation strategy and activates the ADSS which directs the occupants to their optimal exits and away from non-viable exits.

The ADSS consists of two novel signage design concepts, a flashing and running set of lights to highlight the existence of the escape route sign and a flashing red cross to indicate an exit or an exit route is no longer viable. The flashing and running set of lights is introduced into the standard 'green running man' sign (see Figure 1) to enhance the signage affordance (i.e. increasing the detectability of the signs) while maintaining the maximum compliance with existing signage regulations[8]. The conventional static signage system is then turned into a dynamic signage system (DSS), whereas the size and format of the signs and the information conveyed remain unchanged. The dynamic nature of the signs (i.e. the flashing cycle) is only activated during an emergency situation, when the alarm is tripped. The ADSS signs used in the GETAWAY project were developed by UK company EVACLITE Ltd. The effectiveness of the DSS in improving signage detectability was demonstrated[8] under identical experimental settings and conditions as in the previous experiments examining conventional, static signs[4]. The results show that 77% of people 'see' the dynamic sign and 100% of them go on to follow the sign. The second concept, the dynamic method to identify that an exit route is no longer viable, was tested using an international survey to gauge understanding of this new signage concept[8]. The survey results suggest that the proposed negated signage design (see Figure 1) was clearly understood by over 90% of the sample. The flashing light signage design and the negated signage design of the ADSS allow the signage system to highlight both the desirable emergency exit route and the routes that should not be taken.

Figure 1: The flashing light signage design (left) and the negated no entrance signage design (right) used in the ADSS.

In this paper we present a series of full-scale evacuation trials that test the ADSS in a rail station application. The specific purpose of the trials was to assess the effectiveness of the ADSS, which adopted the two signage design concepts, in comparison with the standard emergency exit signage system.

THE EXPERIMENTAL TRIAL METHOD

Based on the successful testing of the flashing light signage design (through the laboratory trials) and the negated signage design (through the international survey) [8], the ADSS was developed through the GETAWAY project, adopting both signage design concepts. The ADSS was then tested within its intended environment (i.e. a realistic application within a rail station) and compared with the results of a similar evacuation trial using the conventional emergency exit signage system.

The trials were designed to test how people might use the two signage systems to find their way out of an unfamiliar station in a presumed emergency situation, without staff intervention. The design of the trials assumes that signage systems can influence evacuee performance and the type of signage used is a factor in this influence. The first trial measured how participants performed using the standard emergency signage system, while the second trial measured the performance of the participants when guided by the ADSS. The two full scale evacuation trials used two different groups of people, with similar demographics.

The trials took place at the Sant Cugat station in Barcelona, Spain. The trials involved one platform of the station that was occupied by the participant population (see Figure 2). The platform is approximately 38 metres long and has four exits (Exit A to D) from left to right. The trials assumed that an incident had occurred that requires the evacuation of the station via the routes available.

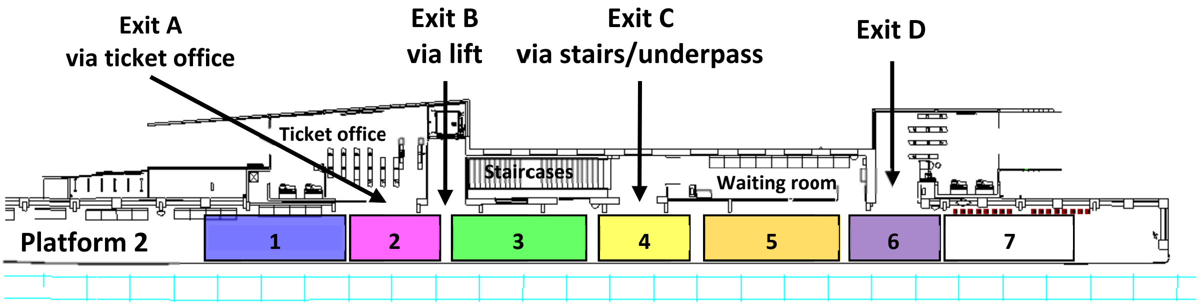

Figure 2: Layout of Platform 2 with the seven coloured boxes for distributing participants.

In order to recreate the intended scenarios of the evacuation trials, a number of participants were needed to populate the station platform to a relatively high population density (2 persons/m^2) in order to reproduce conditions representative of platform conditions during peak station use. To achieve this, 200 participants were required for each trial. Ferrocarrils de la Generalitat de Catalunya (FGC) – the operator of the rail system in Barcelona – recruited the participants from the local area using adverts at their stations, on their website, social networks and local media. A total of 700 volunteers registered for the trials. These volunteers were then selected according to the trial requirements, which included limited knowledge of the selected station and the demographics resembling usual FGC travellers, to produce the final participant population.

On the day of the trials, the participants gathered at another station and were briefed about the trial but were given no specific information concerning the signage systems or the purpose of the trials. Participants were taken to the trial station by train and distributed on the platform at specific locations marked as seven coloured boxes on the platform (see Figure 2) – so they do not experience using the exits. The areas were identified to produce a density of approximately 2 people/m^2 at each location and to ensure consistency of conditions between the trials. The start of the trial was notified by the sounding of a voice alarm. The routes adopted by the evacuating population during the trials were recorded using video cameras for later analysis. On completion of the trails participants were given a questionnaire that was designed to collect information regarding participant exit choice, the factors influencing their decision and their opinions concerning the new signage design concepts. The data derived from the video footage and the completed questionnaires were cross-referenced where possible in order to increase the credibility of the findings.

The first trial, TS2.1 conducted on the 26th May 2013, was to establish a baseline response to standard emergency exit signage. During TS2.1, standard emergency exit signs were used (see Figure 3a). These signs are referred to in the rest of this paper as 'static' signs. All of the emergency signage pointed directly towards the nearest exits (see Figure 4 top). A total of 139 participants eventually took part in TS2.1 who were then exposed to the signage system in place.

(a) (b) (c)

Figure 3: (a) The standard static emergency exit sign and the ADSS (b) flashing exit sign and (c) negated sign.

The second trial, TS2.2, consisting of 152 participants, conducted one week later on the 2nd June, was to assess the participant reaction to the ADSS (see Figure 3b and Figure 3c), which was activated as the same time as the alarm during the trial. The ADSS was configured to direct all participants towards an intended exit, Exit D located at one end of the platform, according to a specific evacuation strategy (see Figure 4 bottom). This was not the nearest exit for the majority of the participant population and therefore required the population to adopt a different behaviour from that exhibited in the first trial. The only intended difference in the trial procedure between the two trials was the signage systems employed (see Figure 4).

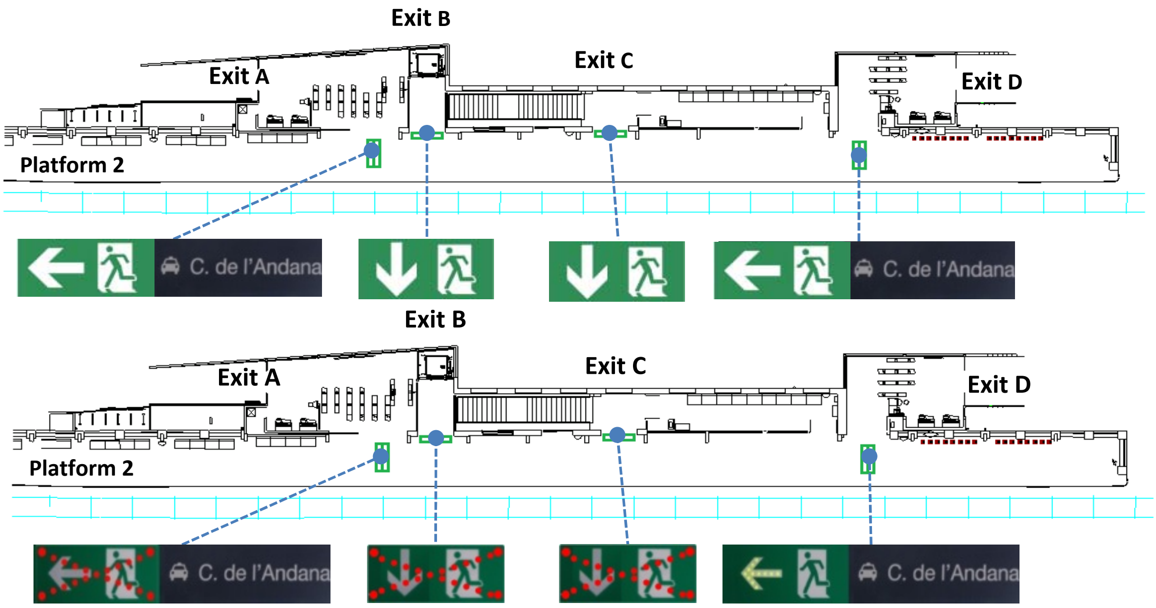

Figure 4: Deployment of the standard signage system in the first trial (top) and the ADSS in the second trial (bottom) on the trial platform.

It should be noted that, unlike the laboratory studies which examined the individuals' interaction with exit signage in relatively ideal conditions[4], during the two full scale evacuation trials there were more influencing factors that potentially had an impact on the participants' exit route/exit selection. These included the surrounding population's actions, the participant's level of familiarity with the platform layout, their initial location on the platform and the presence of the signs. In addition, there was apparent affordance provided by the immediate openings on the platform as a clear indication of way out to the participants. The presence of multiple influencing factors involved in the trials could confound and complicate the examination of the influence of the signage systems.

EXPERIMENTAL RESULTS AND DISCUSSION

The results of the two full-scale evacuation trials TS2.1 and TS2.2 from two data sources (video footage and the questionnaires) are presented and discussed in this section. The video analysis enabled the identification of the primary factors in the trials, such as the number of participants starting in each coloured box on the platform, moving to each exit and the time to evacuate the platform. The video analysis also enabled the identification of some indication of the secondary factors, such as the number of participants observed looking up at the signs during their movement, following other participants and the number of participants observed engaging in group behaviour. The secondary factors were collected in support of the results collected from the questionnaire. These results provided supporting evidence for those factors identified through the video analysis and also enabled some understanding of why actions were performed and what factors influenced the selection of exit routes/exits.

Post-trial questionnaires were used to gain an understanding of the participants' exit route/exit selection and, in particular, identify the factors that influenced them in making this selection during the evacuation. The questionnaire was formed of 12 high-level closed questions, leading to more probing (although still closed) sub-questions in several instances.

Demographics of Participant Population

The demographics of the two populations are broadly similar and representative of users of the FGC system. Almost 20% of both trial populations were over the age of 50. In addition, the two trial populations are also similar in all the other aspects, including the distribution of participants' occupation, participant impairment present during the trials, their level of familiarity with the station and exit awareness.

Of the participant populations, 44.3% in TS2.1 and 44.7% in TS2.2 were unfamiliar with the station (i.e. they never used the station), while 45.0% in TS2.1 and 47.4% in TS2.2 were infrequent users of the station (i.e. they used the station less than once per month).

Results of TS2.1 from Video Analysis – Standard Signage System

Trial TS2.1 was intended to provide a baseline indication of the exit routes used. This trial involved the use of standard emergency exit signs to direct the participants towards all available exits. In effect, this would have been the expected route use had there not been any environmental cues, staff intervention or other procedural measures (including dynamic signage) present to influence performance, apart from the standard signage system. The behaviour exhibited in TS2.2 (where the difference is the introduction of the ADSS into the evacuation procedure) can then be compared to that in TS2.1, particularly the exit use.

TS2.1 involved 139 participants. Table 1 shows the number of participants that started in each of the coloured boxes and then used a particular exit during TS2.1. The number of participants from each coloured box who moved to their nearest exit is highlighted in bold. It was observed that 99% (137 out of 139 participants) of the population moved to their nearest exit; i.e. with no other attempt to redirect people to alternative exits, people typically made use of their nearest exit. It is unclear from the video footage why two participants from the yellow (4) box travelled along the platform to an alternative exit.

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Table 1: Starting and ending locations of participants during TS2.1.

Exit used	Boxes and initial population size							Total	% moved to each exit
	Blue(1)	Magenta(2)	Green(3)	Yellow(4)	Orange(5)	Purple(6)	White(7)		
	21	12	24	19	26	14	23	139	
Exit A	**21**	**12**	**23**	0	0	0	0	56	40.3%
Exit C	0	0	**1**	**17**	**5**	0	0	23	16.5%
Exit D	0	0	0	2	**21**	**14**	**23**	60	43.2%

There were a total of 56 participants using Exit A with the last participant exiting after 33 seconds, 23 participants used Exit C with the last participant exiting in 29 seconds and 60 participants used Exit D with the last participant exiting in 45 seconds. The entire platform was then cleared within 45 seconds. Clearly, there was an even usage of Exit A and Exit D at either end of the platform with fewer participants opting to use the central exit (Exit C). This distribution of exit use may be attributed to the positioning of the coloured boxes whereby only the Yellow (4) box is near the central exit and only a few participants in the Orange (5) and Green (3) boxes were closer to the central Exit C than the outer Exit A and Exit D.

Thus in TS2.1, the majority of the participants (99%) used their nearest exit. The platform was evacuated within 45 seconds (i.e. the time for the last participant to leave the platform) with an even spread of participants using the two end exits (Exit A and Exit D) and a smaller number of participants using the central exit, Exit C. There were very few participants (5%) who were observed looking up at signage during the trial.

Results of TS2.2 from Video Analysis – ADSS

Trial TS2.2 involved the use of the ADSS to direct the participants towards Exit D, according to a specific evacuation strategy, given the nature of the assumed incident (a rapidly developing luggage fire was assumed to occur adjacent to the ticket office of Platform 2). This trial was intended to assess the participant reaction to the ADSS.

TS2.2 involved 152 participants. Table 2 shows the number of participants that started in each of the coloured boxes and then used a particular exit during TS2.2. The number of participants from each box who moved to their nearest exit is highlighted in bold. Note that among the 27 participants who started in the Orange (5) box and used Exit D, 14 of them were initially located nearer to Exit D, while the other 13 were located nearer to Exit C.

Table 2: Starting locations and ending exits of participants and their use of signs during TS2.2.

Exit used	Boxes and initial population size							Total	% moved to each exit
	Blue(1)	Magenta(2)	Green(3)	Yellow(4)	Orange(5)	Purple(6)	White(7)		
	31	20	25	11	27	13	25	152	
Exit A	**13**	**18**	**19**	0	0	0	0	50	32.9%
Exit C	0	0	0	**5**	**2**	0	0	7	4.6%
Exit D	18	2	6	6	**25**	**13**	**25**	95	62.5%
Followed signs	18	2	6	6	11	5*	7*	60	-
Saw & ignored signs	1	1	3	3	0	0	0	8	-

* The number of participants who were identified as seeing the signs from the video analysis.

There were a total of 50 participants using Exit A with the last participant exiting after 35 seconds, 7 participants used Exit C with the last participant exiting in 28 seconds and 95 participants used Exit D with the last participant exiting in 83 seconds. The entire platform was then cleared within 83 seconds. The time to clear the platform was longer in T2.2 compared to T2.1. This is a natural consequence as there were 35 more participants who used Exit D in T2.2 than in T2.1 and some of them were directed to use this more distant exit, resulting in them having to walk the whole length of the platform in order to evacuate.

As expected, among the 52 participants whose nearest exit was Exit D, including 14 starting in the Orange (5), 13 in Purple (6) and 25 in White (7) boxes, 100% of them used this exit during TS2.2. This is similar to the results of TS2.1, in which 99% of the entire population used their nearest exit. However, among the 100 participants whose nearest exit was Exit A or C, including 31 starting in the Blue (1), 20 in Magenta (2), 25 in Green (3), 11 in Yellow (4) and 13 in Orange (5) boxes, only 57% (57) of them moved to one of the two exits in TS2.2, compared again with 99% in TS2.1. Conversely, this means that 43% of the population whose nearest exit was Exit A or C, did not use their nearest exit. Given that the only intended difference between the two trials was the presence of the ADSS (the 'red-cross' no entrance signs at Exit A and C, 'green arrow' entrance sign at Exit D), it is suggested that the ADSS strongly influenced route choice. It should be noticed that this percentage (43%) includes the effect of participants being directed by the flashing light signs (the primary impact of the ADSS) and the effect of some other participants following those who were redirecting away from their nearest exit due to perceiving the no entrance signs (a secondary effect of the ADSS).

The influence of the ADSS on participant exit selection in TS2.2 is further examined for the participants started from different boxes. The participants started in the Blue (1) box were located at the far end of the platform; they had to travel a long distance and pass Exit A and C in order to get to Exit D indicated by the ADSS. Despite the presence of nearer exits on their way, 58% (18 out of 31) of these participants chose to use Exit D. The participants in the Magenta (2) and Green (3) boxes were located next to Exit A. Among them, 10% and 29% respectively moved to Exit D. The relatively higher proportion of people from the Blue (1) box using Exit D than the Magenta (2) and Green (3) boxes may have been due to the actions of a participant starting in the Blue (1) box who decided to use Exit D according to the ADSS, and then also directed several others to do so: a participant's initial choice and subsequent actions may have had an influence on the behaviour of others. It should also be noted that this type of response might also occur during an actual incident. Similarly, among the 11 participants in the Yellow (4) box and 13 participants in the Orange (5) box who were located next to Exit C, 71% (17 out of 24) used Exit D. These participants were closer to Exit D and the flashing sign of the ADSS than the participant started in Blue (1), Magenta (2), Green (3) boxes; therefore, a higher proportion of people followed the ADSS to use Exit D. The fact that participants from these boxes did move to the indicated exit rather than their nearest exits suggests that the ADSS did have some effect on the evacuation of these sub populations.

In total, 63% (95 out of 152) of the entire population used Exit D indicated by the ADSS in TS2.2. This figure includes those participants initially located close to Exit D and those who were redirected to Exit D and therefore, represents the proportion of the population that followed the intended procedural intervention posed by the ADSS. Thus 63% of the population made use of the intended exit indicated by the ADSS.

Table 2 also shows the decision-making of the participants either directly observed or inferred from their exit use. The row with title '*Followed Signs'* lists those using Exit D for whom this exit was not their nearest option. This included those starting in the Blue (1), Magenta (2), Green (3), Yellow (4) boxes and a portion of those starting in the Orange (5) box. The inference here is that those located in these boxes who used Exit D were assumed to have either seen the signs directly or been influenced by someone who had seen the signs (i.e. a primary or secondary effect of the ADSS). For those located nearest to Exit D, i.e. all of the participants in the Purple (6) and White (7) boxes and a portion of those starting in the Orange (5) box, the number of participants clearly seen looking directly at the signs is reported. However, there may have been others who also saw the signs. All of these participants moved to the indicated exit (Exit D) as it was their nearest exit and so no clear conclusion can be drawn on the influence of the signs from the video footage. Finally, the last row in Table 2 shows some participants who were observed directly looking (and/or pointing) towards the signs, but then moved to an exit other than Exit D; i.e. these participants saw and then ignored the signs.

Given the difficulties in establishing participant activities from the analysis of the video footage, the estimate of those being influenced by the ADSS should be considered conservative. The values derived from the video footage are only indicative, with more definitive results derived from the questionnaire analysis discussed in next section.

Effectiveness of the Standard Static Signage System and the ADSS

In TS2.1, 99% of the participants used their nearest exit. However, in TS2.2, 43% of the population whose nearest exit was Exit A or C, did not use their nearest exit. Considering the similarity in the recruited participants' level of familiarity with the station and their positioning on the platform between the two trials, the use of non-nearest exit in TS2.2 is likely to be due to the presence of another influencing factor. Clearly, the ADSS used in TS2.2 was different from the standard signage system used in TS2.1. The nature of the influence of the ADSS on participants' exit selection is further analysed to determine whether the hypothesis that the ADSS influenced performance is reasonable.

In TS2.2, three negated no entrance signs were positioned at Exits A, B and C, while one flashing arrow sign was positioned at Exit D (see Figure 4 bottom). The intended procedure associated with this ADSS configuration was to direct all participants to use Exit D, in clear distinction from Trial TS2.1 where all four static signs pointed towards the nearest exits. The video analysis results show that among the 87 participants who were in the Blue (1), Magenta (2), Green (3), and Yellow (4) boxes, 55 used Exits A-C, while 32 used Exit D. All the other participants whose nearest exit was Exit D (52% in the Orange (5) box and all participants in the Purple (6) and White (7) boxes used Exit D. This represents three distinctive evacuation patterns during TS2.2, considering the participants' initial location, location of nearest exit to them, their choice of exit and the type of signs available on their chosen route that potentially influenced their decision (see Table 3).

Table 3: Evacuation patterns in the trails and available signage as a potential influencing factor.

Evacuation pattern	Number of participants*	Initial location	Nearest exit	Used exit	Type of sign(s) on chosen route	Number of participants noticed sign(s)
TS2.2_P1	59	Box 1-4	Exit A-C	Exit A-C	No entrance sign	45 (76%)
TS2.2_P2	31	Box 1-4	Exit A-C	Exit D	No entrance sign and flashing arrow sign	28 (90%)
TS2.2_P3	56	Box 5-7	Exit D	Exit D	Flashing arrow sign	50 (89%)
TS2.1_P4	149	Box 1-7	Exit A-D	Exit A-D	Standard static sign	118 (79%)

* A few participants from TS2.2 were not included in this table because they started in Box 5-7 and claimed they used Exit A. From the video analysis, no one from these boxes did so; therefore, an error is assumed.

Pattern TS2.2_P1 represents those participants who were nearest to Exit A-C and used one of these exits in TS2.2. Pattern TS2.2_P3 represents those participants who were nearest to Exit D and who used Exit D in TS2.2. In both cases, it is possible that these participants were only exposed to one type of sign: either the no entrance signs (with no additional indication in close proximity identifying a usable exit, leaving participants to use their nearest exit) or the flashing arrow sign.

Pattern TS2.2_P2 includes those participants whose nearest exit was Exit A-C, but chose to evacuate via Exit D in TS2.2. It was likely that they were influenced either directly or indirectly by both the no entrance signs above their nearest exit and the flashing arrow sign indicating the use of Exit D.

In order to compare TS2.2 with TS2.1, a fourth pattern TS2.1_P4 is added to Table 3 to represent the participants in TS2.1 and their evacuation pattern; they used their nearest exit and only the standard exit signs were available and were a potential influencing factor.

In pattern TS2.1_P4, where almost all participants used their nearest exit, 79% (118 out of 149) of the participants claimed to have noticed the emergency exit signs. However, signage only accounted for 26.8% in their exit selection, followed by the influence of surrounding participants which accounted for 18.0%; while the most significant factor (50.7%) was that there was an immediate exit next to them (see Table 4). **These results suggest that in TS2.1 although most of the participants were aware of the standard static signs as a source of information, the signs played a much less important role in their exit selection than the proximity of the exits.** Therefore, in TS2.1 where people used their nearest exit, the information provided by the signs was not the dominant influence on exit selection.

Table 4: Relative significance of influencing factors upon exit selection based on questionnaires.

Evacuation pattern	Surrounding participants	Presence of a nearest exit	Signage	Others
TS2.2_P1	24.6%	46.7%	20.4%	8.3%
TS2.2_P2	14.5%	12.9%	71.0%	1.6%
TS2.2_P3	13.4%	43.8%	39.6%	3.2%
TS2.1_P4	18.0%	50.7%	26.8%	4.5%

In pattern TS2.2_P1, where the participants used their nearest exit, contradicting the information provided by the no entrance signs, 76% (45 out of 59) of the participants claimed to have noticed the signs. However, similar to TS2.1_P4, signage accounted for 20.4% in influencing their exit selection, while the most significant factor (46.7%) was proximity to an exit too (see Table 4). Indeed, the participants of TS2.2_P1 behaved similarly as those in TS2.1_P4; they all used their nearest exits and primarily for the same reason: they predominantly chose their nearest exit rather than utilising the signs.

The ignoring of the negated signage information by the trial participants who exhibited behaviour pattern TS2.2_P1 and the relatively low significance of signage as a source of information to these participants can be explained by the nature of the information conveyed by the negated signs in TS2.2. As indicated previously, the negated signs only provided negative information to the participants whose nearest exits were Exit A-C, but did not provide information concerning a viable alternative exit route (see Figure 4 bottom). For these participants to detect the viable exit, they would have to see the flashing green sign located at Exit D and, given the distance and incident angle it could easily be missed. As a result, the information conveyed by the negated signs was less influential than the proximity of a close exit to the wayfinding decisions of the participants who displayed pattern TS2.2_P1. These results suggest that while the participants in TS2.2_P1 may have perceived the negated sign, they did not perceive the flashing arrow sign further down the platform and so had no other viable option than to use their nearest exit. Therefore, when the participants made use of their nearest exit against the advice of the ADSS (red cross) the information provided by the signs may have been only partially successful in alerting the participants that the exit was not viable, but not providing them with an alternative. **Thus it is important to provide positive information if negative information is being conveyed by the sign.**

In pattern TS2.2_P2, where the participants used Exit D even though it was not their nearest exit, 90% (28 out of 31) of the participants claimed to have noticed the signs. The questionnaire results revealed the relative importance of signage in influencing exit selection. Signage accounted for 71.0% in influencing their exit selection, while the presence of the nearest exit (previously the most significant factor in TS2.2_P1 and TS2.1_P4) only accounted for 12.9% (see Table 4). This suggested that signage played a much more important role in pattern TS2.2_P2 than TS2.2_P1 and TS2.1_P4. In addition, considering the influence of surrounding participants accounted for 14.5%, it is possible that some participants were following others who had already been influenced by the ADSS; i.e. the signs acted as a secondary effect to them. In effect, the actual relative significance of signage might then be higher than 71%. These results suggest that the participants in TS2.2_P2 concluded from the negated signs that their nearest Exit A-C should not be used (detected the negative sign) and that they detected and followed the flashing arrow sign leading them to Exit D (saw the positive sign). These participants **perceived both the negated signs and flashing arrow sign and they treated signage as the most important factor in their exit selection**. In essence, these participants had access to the full set of the procedural information available.

In pattern TS2.2_P3, the participants used Exit D, which was their nearest exit, which was also indicated by the flashing arrow sign above it. Of these participants, 89% (50 out of 56) claimed to have noticed the signs. The questionnaire results show that signage accounted for 39.6% in their exit selection. This is lower than the influence during TS2.2_P2 (71.0%), but double that evident in TS2.2_P1 (20.4%). It should also be noted that the presence of the nearest exit accounted for 43.8%, which is comparable to the relative significance of signage. These results suggest that most participants in TS2.2_P3 perceived the flashing arrow sign and they treated signage and proximity of the exit almost equally in their exit selection. This suggests that it would be unreasonable to state that those located nearest to Exit D and used Exit D did so simply due to proximity – unlike the presence of the standard static signs in TS2.1. **The presence of the flashing arrow sign had at least an equivalent impact on participant exit selection as the proximity of the exits in TS2.2**.

In summary, the participants TS2.1 were typically aware of the standard signage, but typically moved towards their nearest exit independently of the signage, they were drawn simply by the proximity to an exit. The ADSS signage used in TS2.2 had a more influential impact on participant wayfinding (exit selection) than the standard signage in TS2.1. In TS2.2, the negated signs, while conveying to some of the participants that the exit was not appropriate (negative impact) failed to indicate a viable alternative, resulting in these participants discarded the signage information and selected their nearest exit (TS2.2_P1). Negative information alone is insufficient to encourage exit use, and may lead to confusion if no other information is readily available, highlighting the importance of appropriate positioning of the signs. However, some of the participants in TS2.2 noted both the negated signs and the flashing green signs and this combination lead them to use the appropriate exit (TS2.2_P2). The negative information discouraged them from using their nearest exit and the positive information encouraged them to use the appropriate, but more distant exit. Finally, those who simply detected the flashing green sign made use of their nearest exit, the presence of the flashing green sign supporting the decision to use their nearest exit (TS2.2_P3).

It was also found through the questionnaire analysis that 65.6% of the participants who saw at least one of the ADSS signs stated that the flashing lights in the arrows assisted them in selecting which way to go. Furthermore, 61.5% of the population agreed that the flashing lights in the arrow assisted them in making a quick decision. In addition, 51.0% agreed that the flashing red cross indicated which exit should not be used.

While it is difficult to differentiate between the direct (e.g. detected the ADSS and modified route choice) and indirect (e.g. followed someone who had detected the ADSS and modified their route choice) impact of the ADSS, a majority of the participants (63%) followed the intended evacuation route when the ADSS was active, without staff intervention or specific instructions. The proportion following the ADSS guidance could have been improved if both negative and positive information was available at each decision point. This was an issue of signage positioning and information completeness rather than the effectiveness of the ADSS. Where incomplete signage information was available, while this was understood by the participants, it was acted upon along with other considerations, such as proximity to an exit. The effectiveness of the ADSS may have been increased had more of the participants had access to both positive and negative signage information.

CONCLUSIONS

An Active Dynamic Signage System (ADSS) was developed as part of the EU FP7 GETWAY project to addresses the limitations of conventional static emergency signage systems. The ADSS enables the building Incident Manager to direct occupants to follow an intended near optimal evacuation route based on available situational information by activating the appropriate dynamic signs. The ADSS was developed in two steps. The first step, reported in earlier publications, involved the development of the 'Dynamic Signage System', a concept designed to enhance the affordance of the emergency sign. This was tested in full-scale laboratory trials designed to examine an individual's response to the new signage concept. The second step, reported in this paper, involved the development of the 'Active Dynamic Signage System'. This is designed to inform the building population of the preferred (optimal) evacuation route. The ADSS concept was tested in two full-scale evacuation trials in a rail station.

The first trial TS2.1 was conducted to establish a baseline response to standard static emergency exit signage. The results of the trial demonstrated that 99% of the 139 participants exited the station using their nearest exit, of which there were three. Although the participants' exit selection was consistent with the emergency signage which pointed directly towards the nearest exits, according to the survey results, only 26.8% of participant exit selection was influenced by the presence of the standard signs. The most significant factor, which accounted for 50.7% of the exit selection, was the proximity of the exit. These results suggest that the most influential wayfinding factor in these trials was proximity to an exit.

The second trial TS2.2 was intended to assess the participant reaction to the ADSS, which was configured to direct all 152 participants towards a single exit located at one end of the same platform. This was not the nearest exit for the majority of the population and therefore required the population to modify their normal desire to exit via the nearest exit, as demonstrated in TS2.1. The results of the trial showed that almost half of the participants (43%) whose nearest exit was not the targeted exit were successfully redirected and utilised the identified exit. Furthermore, 63% of the total population used the indicated exit; i.e. followed the route indicated by the ADSS. This included those drawn to the exit and those initially located nearest to it. These results were achieved without staff intervention in the form of fire marshals directing the movement of the participants and without providing the participants with specific information concerning the nature of the ADSS.

Furthermore, analysis of the questionnaire data suggested that most (76%) of the participants in TS2.2 who did not use the indicated exit had detected the negated signs indicating not to use their nearest exit. However, while the negated sign suggested that the exit should not be used, it did not offer a viable alternative to their nearest exit. This suggests that it is insufficient to simply provide negative wayfinding information. To be effective, both negative and positive information should be provided if the population is to follow the information provided.

The main conclusion of these trials is that the ADSS has a greater effect on route choice than standard static signage system and therefore are more likely to promote the adoption of specific emergency evacuation routes than would otherwise be the case, especially where evacuees are required to adopt routes not entirely based on proximity.

The final part of the GETAWAY project will demonstrate the effectiveness of the IADSS – the ADSS with added automatic intelligent identification of the optimal evacuation route - in full-scale trials at the same rail station used to demonstrate the ADSS. Furthermore, the IADSS trials will incorporate a modified ADSS that conveys both negative and positive exiting information.

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