

New evacuation sign "NO ENTRY"

Robert PIEC^{*1}, Barbara SZYKULA-PIEC², Rafał WRÓBEL², Marcin CISEK³

¹ *Institute of Safety Engineering, The Fire University, Warsaw, Poland*

² *Faculty of Security Engineering and Civil Protection, The Fire University, Warsaw, Poland*

³ *Emeritus academic, Faculty of Security Engineering and Civil Protection, The Fire University, Warsaw, Poland*

Abstract

This study addresses concerns about the effectiveness of conventional evacuation signs in directing occupants during emergencies, particularly in situations involving obstacles like smoke, flames, or high temperatures. The research explores innovative solutions to enhance safety during evacuations, focusing on two main approaches: the Active Dynamic Signage System (ADSS) and the dynamic evacuation control system. The study introduces the concept of 23 different pictograms utilizing LED technology, with the "no-entry" sign receiving the highest rating during evaluations.

The research emphasizes the importance of dynamic evacuation control systems, suggesting the integration of signs forbidding entry into hazardous spaces. The study concludes that efficient evacuation is crucial for safety culture, necessitating a discussion on the introduction of a new pictogram – the NO ENTRY sign – into the evacuation sign catalog. The authors advocate for the adoption of a dynamic evacuation lighting system and offer an open license for the proposed pictograms to encourage broad discourse.

Keywords: evacuation signs, safety culture, dynamic evacuation lighting, pictograms, NO ENTRY sign, safety in buildings

* **Corresponding author:** E-mail address: (rpiec@apoz.edu.pl) Robert PIEC

1 Introduction

Highlights

Evacuation Signage Enhancement: This study critically examines the effectiveness of conventional evacuation signs, proposing innovative solutions for improved safety during emergencies.

Active Dynamic Signage System (ADSS): ADSS introduces flashing LEDs to standard emergency exit signs, drawing attention to escape routes and alerting the public to potential dangers.

Dynamic Evacuation Control System: Emphasizing the importance of dynamic control, the study suggests supplementing evacuation signs with a forbidding-entry indication to hazardous spaces.

For many years, a standard approach was the simultaneous evacuation of the entire building. The disadvantages of this approach were noted after analysis of evacuation cases during which fatalities occurred. The results of the analysis indicated a reduction in the evacuation effectiveness of the people crowding the roads and emergency exits. To address this problem, a phased evacuation process was introduced with the main goal of alleviating congestion. Another element that improves evacuation efficiency is the introduction of a dynamic evacuation direction system that optimizes the evacuation process [1, 2]. It makes it possible to propose evacuation directions in a building in real time, thus responding to information about the location and development of the threat.

In research related to crowd evacuation, much attention has been paid to evacuation scenarios and critical, hazardous conditions during evacuation [3, 4]. The results of studies related to evacuating people from buildings indicate that it is worthwhile to control the movement of people in real time to minimize the likelihood of dangerous situations that threaten evacuees [5].

Effective real-time coordination of evacuees can be achieved by implementing systems that dynamically inform pedestrians of safe exits [6, 7] and evacuation routes [8].

Research on real-time crowd evacuation has made it possible to create a mechanism for providing dynamic information about a safe evacuation route to people at risk. The information provided by an evacuation management system must be clear and easy to apply [9].

Evacuation signs are standardized, with EN ISO 7010:2020 [10] introduced in Europe. In Filippidis et al. [11] proposed a dynamic signage design, Active Dynamic Signage System (ADSS), by incorporating flashing green LEDs into the arrows of conventional exit signs. Analysis of actual building evacuations indicates that sometimes a hazard can occur on escape routes. However, the catalogue of signs included in the standard does not include a sign prohibiting entry into at-risk spaces in buildings equipped with directional dynamic lighting.

The article presents the results of a study evaluating a proposal for a new "NO ENTRY" sign that would dynamically replace the evacuation sign above the door leading to the fire-prone space. So far, when a building is equipped with a dynamic signage system - signs leading to fire-affected spaces have only been turned off.

2 Methodology of conducted research

The study included 3 stages:

- Graphic sign proposal stage;
- Pilot study phase;
- The stage of research proper.

In the first stage, a set of graphic signs representing the "NO ENTRY" sign was prepared. Graphic signs were proposed by experts in fire safety engineering - 10 lecturers from the Main School of Fire Service (Fire University) in Warsaw, Poland. The following technical limitations were assumed: 3 colours: white, green and red (used in signs from EN ISO 7010:2020), format 11 x 11 square areas, 23 graphic signs were developed so that the newly created signs could be used in commercial solutions.

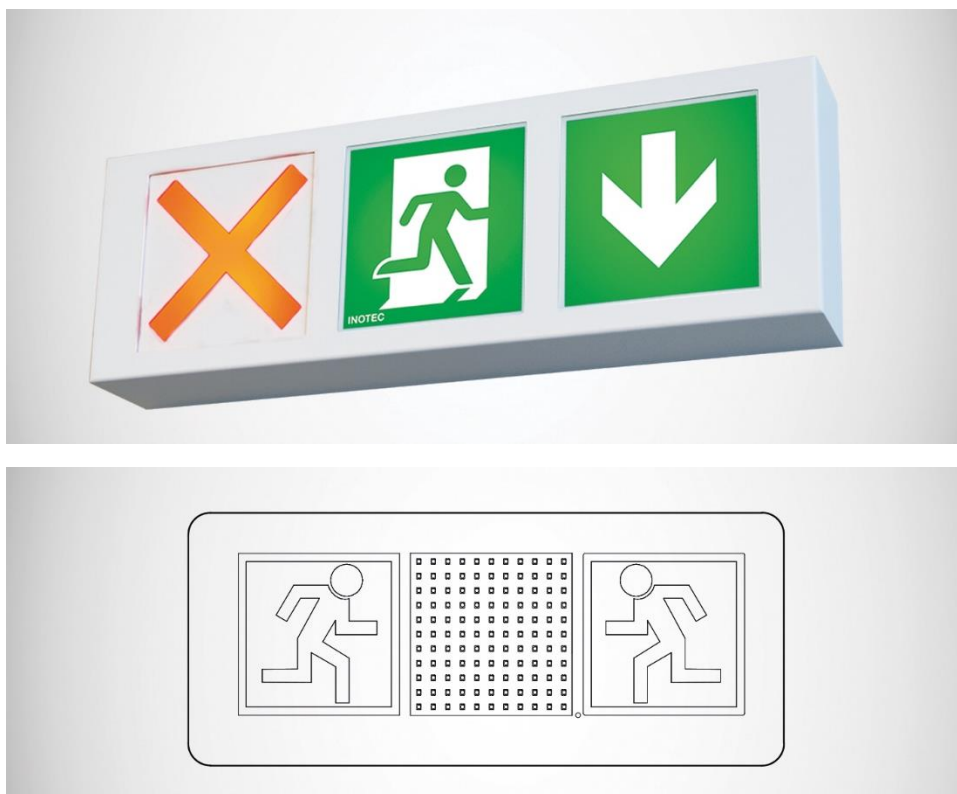


Figure 1. AMATECH dynamic evacuation control system luminaires

Source: <http://www.amatech.eu/systemy-i-oprawy-oswietlenia-awaryjnego/dynamiczny-system-kierowania-ewakuacja/dynamiczny-system-kierowania-ewakuacji%20C4%85-dke-szczegoly>, 5.04.2023 [12]

The next (second) stage was a pilot survey mainly aimed at selecting a narrower set of signs to enable proper research on a large group of respondents.

The pilot study was conducted in two stages:

- Stage 1 - from December 2020 to January 2021. (100 people);
- Stage 2 - from November 2021 to February 2022 (164 people).

The survey questionnaires were made available using social media and sent via email, and the target group surveyed was mainly people involved in fire protection. Data was collected using a specially prepared Google Forms questionnaire. Completing and submitting the questionnaire implied consent to participate in the study. Respondents were aware of this, it was clearly emphasized in the survey questionnaire. The submitted survey results were collected and reviewed to eliminate erroneous or illegible samples. The survey was anonymous, the data collected prevented the identification of the person surveyed.

In the first pilot questionnaire (stage 1), respondents were asked to choose the most appropriate, only one, from a set of presented signs [13].

In the second pilot study, respondents were asked to rate each of the "NO ENTRY" sign designs on a scale of 1 (illegible, unintelligible sign) to 5 (legible, understandable sign). In addition, to characterize the study group, respondents were asked to provide demographic data age, gender, education, form of disability, place of residence) and to specify experience and knowledge of evacuation, as well as to assess the quality of current evacuation signs.

After the pilot study determined the group of characters most frequently chosen by respondents (limited to 6 characters), a main survey was conducted, lasting from July 2022 to February 2023, and 449 responses were collected. The survey questionnaire was shared using social media - LinkedIn and Facebook, and was sent via email to a selected group of people in Poland, mainly related to fire safety engineering. It was assumed that those associated with fire safety would have more experience with people evacuation which would increase the value of the responses. The data was collected using a specially prepared questionnaire from SurveyLab. For the entire population of people in Poland - about 38,000,000 people - the error is evaluated as 5%.

In the main survey, the question sheet consisted of the first part of demographic questions (age, gender, education, place of residence) and a question about professional relationship with fire protection. In the next part, respondents were asked to evaluate the legibility of the given signs NO ENTRY and to assign values from 1 to 6 to the proposed signs NO ENTRY, respectively, where: 1 - meant the pictogram least associated with the entry ban, 6 - meant the pictogram most associated with the entry ban. Next, respondents were asked to choose one pictogram that should signify, a dynamic NO ENTRY sign. In subsequent questions, respondents were asked to determine the need for the proposed signs for escape routes and exits, and to indicate the location of the NO ENTRY sign.

3 Results

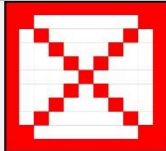

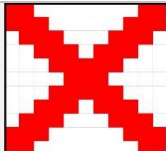
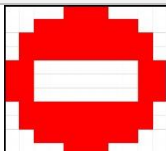
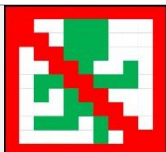
Stage I. Proposals for graphic signs depicting the NO ENTRY sign

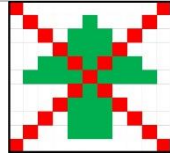
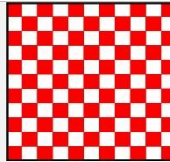
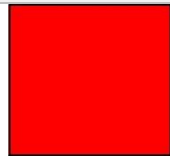
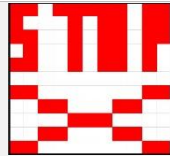
The result of the first stage of work-study was 23 proposals NO ENTRY. All the proposed signs are presented in the section describing the results of the pilot study.

Phase II. First pilot study

In the first stage of the pilot study, respondents (100 people) were asked to choose the "most appropriate" (only one) in the opinion of respondents dynamic evacuation sign indicating "NO ENTRY", the results presenting the number of indications of specific proposals are shown in Table 1.

Table 1. Results of the pilot study to select the most appropriate, in the opinion of respondents, dynamic evacuation sign indicating "NO ENTRY"

Mark number in the study	Graphic proposal	Number of people pointing to the sign
Mark No. 1		4
Mark No. 2		14
Mark No. 3		8
Mark #5		59
Mark No. 8		10

Mark No. 11		1
Mark No. 12		1
Mark #13		2
Mark #16		1

Source: Authors' Authors' own study.

Those completing the survey indicated only 9 signs. The largest number of respondents (59%), chose sign No. 5. In second place was sign No. 2 considered the most appropriate by 14% of those asked. The third most frequently chosen sign proposal was sign No. 8, which was favoured by 10% of the audience. The next sign indicated by 8% of the respondents was sign No. 3. The other signs presented were indicated by no more than 5 people. The signs that no one indicated were omitted from the presentation of the survey results in Table 1.

Phase II. Second pilot study

Regardless of the results of the first pilot study, the second pilot study asked respondents (164 people) to rate the legibility of each sign on a scale of 1 to 5. Respondents were also asked to provide demographic data (Table 2), respondents' experience and knowledge of evacuation (Table 3) and to rate the quality of current evacuation signs in terms of their comprehensibility, visibility and legibility (Table 4). Information on the characteristics of the subjects is shown in Table 2.

Table 2. Demographic variables of the subjects

Criterion	Breakdown	N (%) / other
sex	Woman Male	24 / 14.63 % 140 / 85.37 %
age	Arithmetic average Standard deviation Minimum Maximum	37.95 7.75 24 69
form of disability	No declared disability Person with a disability	155 / 94.51 % 9 / 5.49 %
education	Medium Post-secondary (or higher incomplete). Higher	1 / 0.61 % 3 / 1.83 % 160 / 97.56 %

residence	Urban areas	123 / 75 %
	Non-urban areas	39 / 23.78 %
	Other	2 / 1.22 %

Source: Authors' own study.

Significantly more men participated in the survey 86%. The average age of respondents is 38 years. Disability was declared by 9 people (5.49%). The survey questionnaire was filled out mostly by people with higher education (98 %) living mostly (75 %) in urban areas. The distribution of responses to questions related to respondents' experience and knowledge of evacuation is presented in Table 3.

Table 3. Distribution of responses to questions related to respondents' experience and knowledge of evacuation

Question	Answers	N (%) / other
Have you been part of an evacuation during a real emergency or false alarm?	No	86 / 52.44 %
	Yes	73 / 44.51 %
	I don't remember	5 / 3.05 %
Have you been a participant in an evacuation drill?	No	14 / 8.54 %
	Yes	147 / 89.63 %
	I don't remember	3 / 1.83 %
Do you think trial evacuations should take place.	More often than once a quarter	4 / 2.44 %
	Once a quarter	21 / 12.8 %
	Once every six months	58 / 35.37 %
	Once a year	70 / 42.68 %
	Other	11 / 6.71 %
Do you know the meaning of evacuation signs?	No	1 / 0.61 %
	Yes	140 / 85.37 %
	Yes, but not all	23 / 14.02 %
How familiar are you with evacuation routes at your place of work/teaching:	Medium	14 / 8.54 %
	Well	47 / 28.66 %
	Very well	103 / 62.80 %
Do you know where the assembly point for evacuation is located at your place of work or study?	No, I don't know	7 / 4.27 %
	I'm not sure	20 / 12.20 %
	Yes, I know	127 / 77.44 %
	There is no such place	10 / 6.10 %

Source: Authors' own study.

More than half of respondents (52%) have not participated in an evacuation during either a real emergency or a false alarm. In contrast, the vast majority (90%) have participated in evacuation drills. Those surveyed believe that it is worthwhile to hold evacuation drills frequently, with 43% indicating once a year and 35% indicating once every six months. Only one person declared that they were not familiar with evacuation signs. The majority of respondents (91%), declared that they knew the evacuation routes at their place of work or study well or very well. Knowledge of the assembly point for evacuation at the workplace or study site was marked by 77%.

An assessment of the quality of current evacuation signs in terms of their intelligibility, visibility and legibility (scale of 1 to 5) is presented in Table 4.

Table 4. Distribution of ratings of the quality of current evacuation signs in terms of their intelligibility, visibility and legibility

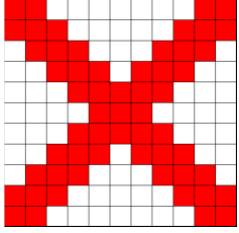
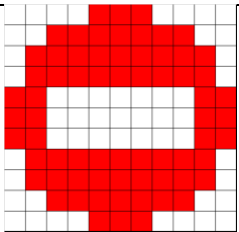
Question	Answers	N (%) / other
Assessing the quality of current evacuation signs in terms of their intelligibility of visibility	Disposition Colour Size Shape	3.81 4.13 3.62 3.93
Evaluates the quality of current evacuation signs for legibility	Colours Backlighting (for illuminated signs) readability of pictograms	4.02 3.99 3.59
Do you see the need for new technologies for marking escape routes and exits that, in the case of, for example: smoke in one stairwell, adapt to the current situation in the facility and, for example: change the displayed direction of evacuation to another safe route or another emergency exit?	No, I think the current evacuation markings are sufficient Yes, I see the need for it I have no opinion	20 / 12.20 % 130 / 79.27 % 14 / 8.54 %
Please give your opinion on how visible the sign would be depending on how it was made On a scale of 1 (invisible sign) to 5 (visible sign)	Sign made of photoluminescent materials Illuminated sign Illuminated sign and additionally flashing	3.15 4.03 4.37

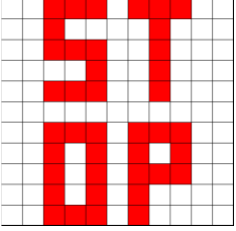
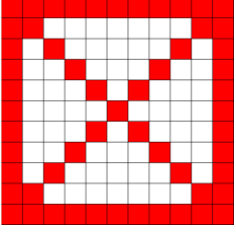
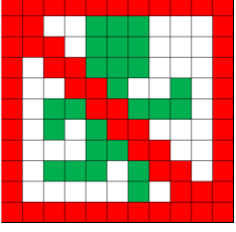
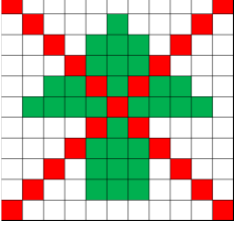
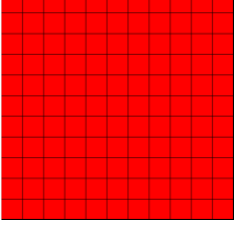
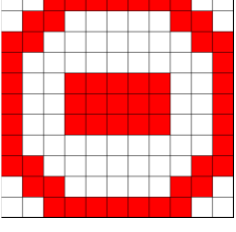
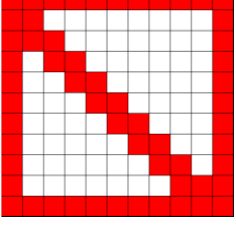
Source: Authors' Authors' own study.

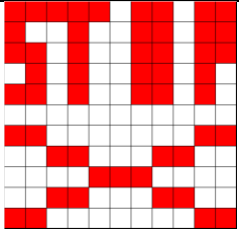
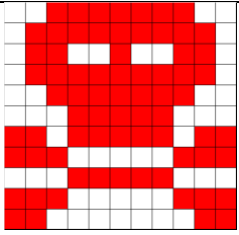
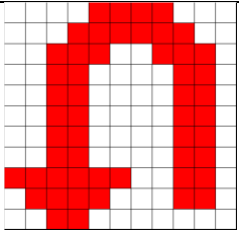
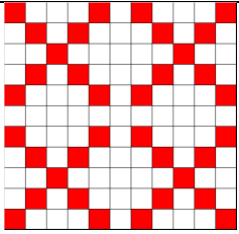
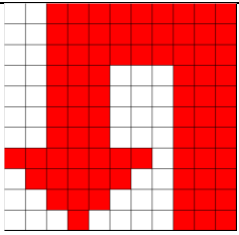
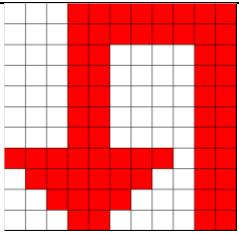
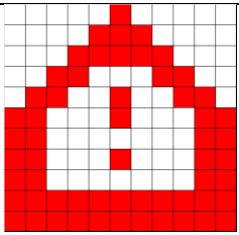
Respondents positively assessed the quality of current escape signs in terms of their intelligibility, visibility and legibility - all parameters were rated an average of 4 points on a scale of 1 to 5. The need for new technologies for marking escape routes and exits was seen by more than 79% of respondents. An additionally flashing illuminated sign was indicated as the most visible.

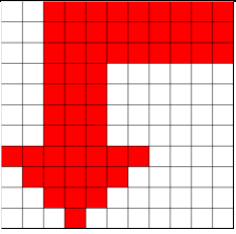
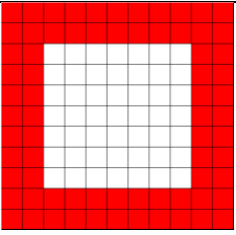
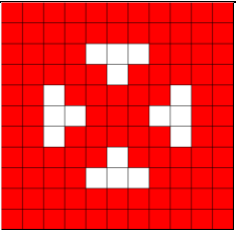
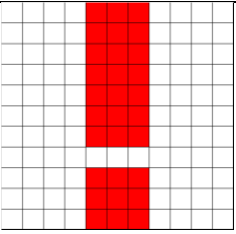
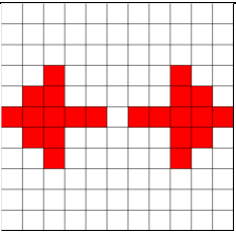
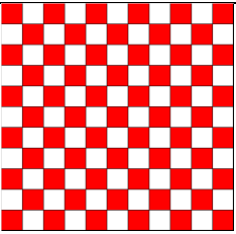
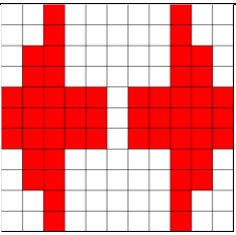
In the following questions, respondents were asked to respond to the "NO ENTRY" sign designs. Table 5 presents the average ratings (obtained from the responses of 164 respondents) for each of the 23 signs considered, as well as the location of the projects' ratings.

Table 5. Average rating and ranking of the "NO ENTRY" sign designs, which would dynamically replace the evacuation sign leading to the fire-prone space

Mark	average	investment
	4.15	1
	3.4	2

	3.38	3
	3.23	4
	2.96	5
	2.88	6
	2.55	7
	2.4	8
	2.27	9

	2.27	9
	2.18	11
	2.15	12
	2.12	13
	2.12	13
	2.12	13
	2.03	16

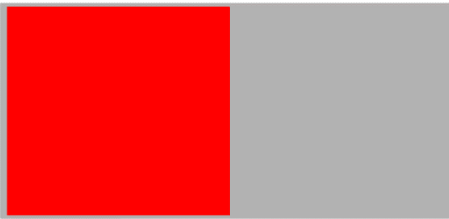

	1.93	17
	1.92	18
	1.59	19
	1.56	20
	1.55	21
	1.53	22
	1.49	23

Source: Authors' Authors' own study.

In the survey, the highest ratings were given to signs resembling the X symbol, with an average score of 4.15; a sign resembling a no-entry sign, with an average of 3.4; and a sign resembling the STOP sign, with an average of 3.38.

The next question asked the public to rate on a scale of 1 (illegible, incomprehensible sign) to 5 (legible, comprehensible sign) the design for the placement of a "NO ENTRY" sign and an "Emergency Exit" sign. The signs would be placed as shown in Figure 4. The averages of the ratings from this survey, relating to the 2 proposals, are presented in Table 6.

Table 6. Evaluation of the design of the placement of the "NO ENTRY" sign and the "Emergency Exit" sign.

Description	Sign proposal	Average	Deposit
"NO ENTRY" with a faded "Emergency Exit" sign.		2.41	1
"NO ENTRY" together with highlighted "Emergency Exit" sign		2.36	2

Source: Authors' own study.

Respondents rated the proposal "NO ENTRY" with the "Emergency Exit" sign turned off slightly better than "NO ENTRY" together with the highlighted "Emergency Exit" sign.

Based on the results of the pilot study conducted, part of the main study (stage 3) it was proposed to limit further research to a few of the best-rated proposals for the "NO ENTRY" sign. The six proposals for the "NO ENTRY" sign, subjected to further testing in the main - stage 3 research, are presented in Figure 1.

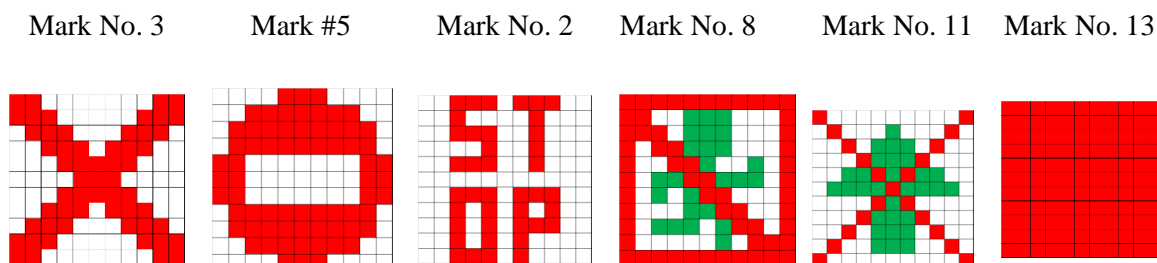


Figure 2. Six signs NO ENTRY, which had been further studied in the main stage of the study

Source: Authors' Authors' own study.

4 Main study

A total of 449 people took part in the main survey, 59% of them men, the average age of respondents was almost 40 years. Most people have a university degree (80%) and live in the city (76%). Demographic variables are described in Table 7.

Table 7. Demographic variables of the subjects

Criteria	Answers	N (%)
Gender	<i>Woman</i>	183 / 41 %
	<i>Male</i>	256 / 59 %
age	<i>Arithmetic average</i>	39.41
	<i>Minimum</i>	16
	<i>Maximum</i>	67
education	<i>higher</i>	359 / 80 %
	<i>post-secondary</i>	19 / 5 %
	<i>average</i>	68 / 15 %
	<i>basic vocational</i>	1 / 0 %
	<i>middle school</i>	1 / 0 %
	<i>basic</i>	1 / 0 %
residence	<i>Village</i>	109 / 24 %
	<i>City up to 50,000.</i>	97 / 21 %
	<i>City of 50,000 to 150,000.</i>	66 / 15 %
	<i>A city of 150,000 to 500,000.</i>	26 / 6 %
	<i>A city over 500,000.</i>	151 / 34 %

Source: Authors' own study.

The majority of respondents - 62% - were involved in fire protection (Figure 2).



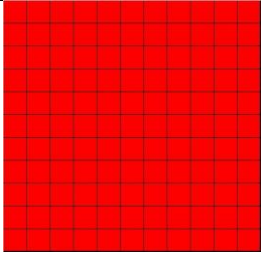
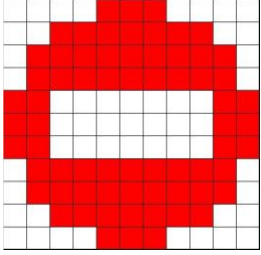
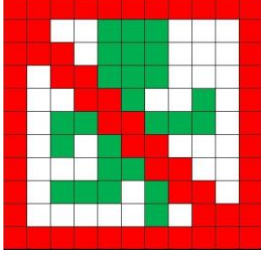
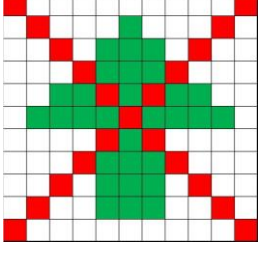
Figure 3. Distribution of responses to the question, "Is your learned or practiced profession related to fire protection?"

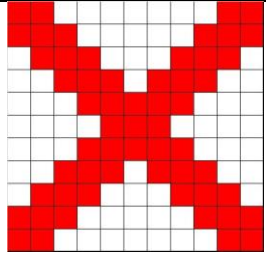
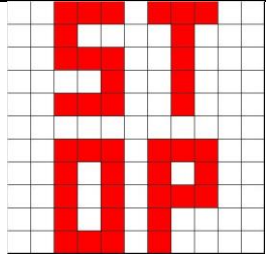
Source: Authors' own study.

The following questions attempted to identify the pictogram that best represents the NO ENTRY into the danger space.

For this purpose, respondents were asked to rate the legibility of the given signs NO ENTRY on a scale of 1 to 5, where 1 - meant low legibility, and 5 - meant very high legibility. Table 8 presents the values of the averages relating to the legibility of the evaluated pictograms - selected proposals for the NO ENTRY sign.

Table 8. Average ratings relating to the legibility of pictograms - selected proposals for the sign NO ENTRY

No.	Mark	Answers			Average
		Evaluation	%	Answers	
13 Red square		Evaluation			2.31
		1	46 %	209	
		2	14 %	62	
		3	17 %	76	
		4	7 %	32	
		5	16 %	70	
5 Entry ban		Evaluation			3.87
		1	6 %	26	
		2	8 %	36	
		3	18 %	83	
		4	29 %	131	
		5	39 %	173	
8 Green man		Evaluation			3.17
		1	14 %	62	
		2	19 %	85	
		3	24 %	108	
		4	23 %	104	
		5	20 %	90	
11 Green arrow		Evaluation			2.93
		1	18 %	81	
		2	18 %	82	
		3	30 %	132	
		4	21 %	95	
		5	13 %	59	

3 Symbol X		Evaluation	%	Answers	3.51
		1	9 %	41	
		2	14 %	61	
		3	22 %	99	
		4	27 %	122	
		5	28 %	126	
2 Stop		Evaluation	%	Answers	3.63
		1	7 %	33	
		2	12 %	52	
		3	22 %	101	
		4	28 %	125	
		5	31 %	138	

Source: Authors' own study.

Respondents were then asked to assign values from 1 to 6 to the proposed NO ENTRY signs, respectively, where: 1 - meant the pictogram least associated with the NO ENTRY, 6 - meant the pictogram most associated with the NO ENTRY. The distribution of responses is presented in Table 9.

Table 9. Distribution of responses to the question relating to the level of association of the sign design with the entry ban on a scale of 1 - 6

Mark / rating	1	2	3	4	5	6	Average points (weighted)
red square	299	50	21	27	17	36	1.94
red square - %	67 %	11 %	5 %	6 %	4 %	8 %	
green arrow	32	111	126	81	66	30	3.29
green arrow - %	7 %	25 %	28 %	18 %	15 %	7 %	
symbol X	19	133	95	81	67	53	3.45
symbol X - %	4 %	30 %	21 %	18 %	15 %	12 %	
no-entry road sign	28	30	46	68	109	168	4.57
no-entry road sign- %	6 %	7 %	10 %	15 %	24 %	37 %	
stop	21	50	85	105	118	70	4.02
stop - %	5 %	11 %	19 %	23 %	26 %	16 %	
green man	50	75	76	87	72	92	3.73
green human - %	11 %	17 %	17 %	19 %	16 %	20 %	

Source: Authors' own study.

In the next question, respondents were asked to choose one pictogram that should signify, a dynamic NO ENTRY sign. The percentage distribution of responses is presented in Table 10.

Table 10. Percentage distribution of responses to the question of which of the evaluated pictograms should mark a dynamic sign prohibiting entry

	%	Answers
X symbol	16 %	70
no-entry road sign	38 %	171
red square	3 %	16
green man	21 %	93
stop	15 %	68
green arrow	7 %	31

Source: Authors' own study.

The next question asked respondents to determine the need for proposed signage for escape routes and exits that, in the event of, for example: smoke in one stairwell, adjusts to the current situation in the facility and, for example: changes the displayed escape direction to another safe route or another emergency exit. The distribution of respondents' answers to this question is presented in Table 11.

Table 11. Evaluation of the need for proposed signage for escape routes and exits that, in the event of smoke in one staircase, adjusts to the current situation in the facility to change the displayed direction of evacuation to another safe route or another emergency exit

	%	Answers
Yes - I see the need for it	80 %	359
No - I think the current escape signs are sufficient	9 %	39
I have no opinion	10 %	47
None of the above	1 %	4

Source: Authors' own study.

Respondents were also asked how the sign should be displayed assuming that the selected sign would be used in place of the red square. The possible two display options are indicated in Figure 3.

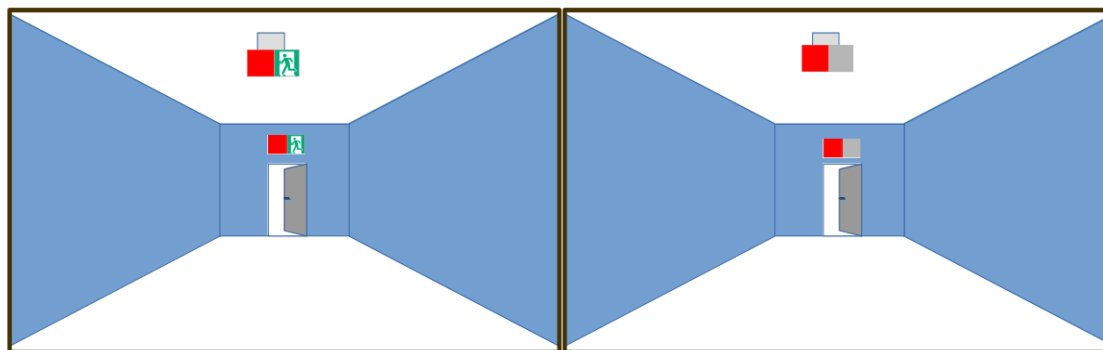


Figure 4. Possible variants of displaying the no-entry sign together with the traditional "Emergency exit" sign

Source: Authors' own study.

Results - the quantitative and percentage distribution of respondents' answers to this question are presented in Table 12.

Table 12. Evaluation of the display of the no-entry sign together with the traditional "Emergency exit" sign

This sign is displayed together with the traditional "Emergency Exit" sign highlighted - image on the left	This sign is displayed with the traditional "Emergency Exit" sign turned off - image to the right	I have no opinion
38 %	50 %	12 %
169	226	54

Source: Authors' own study.

5 Discussion

Evacuation signs are used in buildings to direct occupants to a safe location in the event of fire and other emergencies [14, 15]. Despite the standardized method of marking escape routes, their effectiveness has sometimes been questioned [16, 17]. Conventional escape route marking systems have sometimes been ineffective. Studies show that only 38% of people notice conventional evacuation signs [18]. They also point to numerous experiments and analyses of real events [19, 20, 21]. It is therefore reasonable to look for new solutions. One such solution is the dynamic signage project, Active Dynamic Signage System (ADSS), which introduces flashing LEDs to conventional signs. ADSS uses flashing, glowing green LEDs in the arrow of a standard emergency exit sign to draw attention to the sign. ADSS also alerts the public to the danger on the emergency exit route by placing a simple red cross on the sign.

Another solution to improve the level of safety during the evacuation of people proposed by fire safety engineering (IBP) is the dynamic evacuation control system. The idea behind this system is to direct people so that they leave a threatened facility as quickly as possible without entering hazardous spaces. To realize its full potential, it is necessary to supplement the set of evacuation signs with a sign forbidding entry into the hazardous space.

In the research presented here, a concept of 23 different pictograms possible with LED technology used in emergency lighting, among other applications, is presented. This is not a closed catalogue and other sign designs or other technology can be proposed. In the presented research, the pictogram resembling a no-entry road sign received the highest rating.

The results obtained from the third stage of the research, i.e. the main survey, allowed us to obtain an average rating of the legibility of each of the six pictograms presented, as well as a weighted average indicating the level of association of the design of each of the 6 signs with the entry ban. In the survey, which aimed to examine which of the evaluated pictograms (sign designs) should signify a dynamic entry ban, as many as 38% of respondents thought that the sign resembled a B-2 road sign signifying "no entry". At the same time, 80% of respondents indicated, to the answer, that they see the need for the proposed signs for escape routes and exits, which, in the case of, for example: smoke in one staircase, adapt to the current situation in the facility and, for example: change the displayed direction of evacuation to another safe route or another emergency exit. A variant of displaying the no-entry sign together with the traditional "emergency exit" sign 50% of respondents see that above the entrance to a fire-prone space, the "NO ENTRY sign should be displayed together with the turned off emergency exit sign."

5 Conclusions

Efficient evacuation from buildings is one of the basic rules of safety culture. Inherent in every building are evacuation signs directing a crowd of people to a safe place. Sometimes, however, there are obstacles along evacuation routes, such as smoke, high temperatures, flames or poisonous gases, which pose a danger to people moving through. In order to minimize the risk of injury or death to evacuees moving along static evacuation routes,

it is recommended that a dynamic evacuation lighting system should be introduced. It is therefore necessary to initiate a discussion related to the introduction of a new pictogram in the catalogue of evacuation signs - the NO ENTRY sign. In order to conduct a broad discussion, the authors declare their willingness to grant an open license for the pictograms presented in the study. The results of the study indicate the need for a new sign resembling a road sign prohibiting entry. The pictogram selected through the main study, denoting the recommended NO ENTRY sign that should be displayed above the door leading to the fire-prone space, is presented in Figure 5.

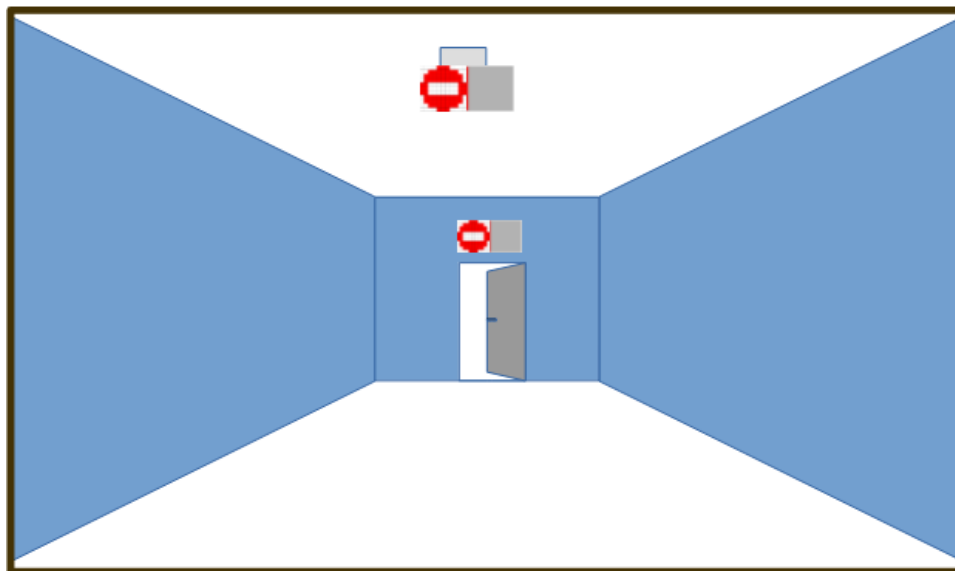


Figure 5. The pictogram selected through the main research to denote the recommended no-entry sign that should be displayed above the door leading to the fire-prone space

Source: Authors' own study.

Bibliography

- [1] Fang, H.; Lo, S.; Lo, J.T.Y. Building Fire Evacuation: An IoT-Aided Perspective in the 5G Era. *Buildings* 2021, 11, 643. <https://doi.org/10.3390/buildings11120643>
- [2] Marcin Cisek, Michal Kapalka, Evacuation Route Assessment Model for Optimization of Evacuation in Buildings with Active Dynamic Signage System, *Transportation Research Procedia*, Volume 2, 2014, Pages 541-549, ISSN 2352-1465, <https://doi.org/10.1016/j.trpro.2014.09.094>.
- [3] Helbing, Dirk & Mukerji, Pratik. (2012). Crowd Disasters as Systemic Failures: Analysis of the Love Parade Disaster. *EPJ Data Science*. 1. 10.2139/ssrn.2191620.
- [4] Murakami H., Feliciani C., Shimura K., Nishinari K. A system for efficient egress scheduling during mass events and small-scale experimental demonstration, *Royal Soc. Open Sci.*, 7 (2020), Article 201465, 10.1098/rsos.201465,
- [5] Miguel A. Lopez-Carmona, Alvaro Paricio Garcia, Adaptive cell-based evacuation systems for leader-follower crowd evacuation, *Transportation Research Part C: Emerging Technologies*, Volume 140, 2022, 103699, ISSN 0968-090X, <https://doi.org/10.1016/j.trc.2022.103699>.
- [6] Bi H., Gelenbe E. A survey of algorithms and systems for evacuating people in confined spaces, *Electronics*, 8 (711) (2019), 10.3390/electronics8060711
- [7] Lopez-Carmona M.A., Paricio Garcia A., CelleVAC: An adaptive guidance system for crowd evacuation through behavioral optimization, *Saf. Sci.*, 139 (2021), Article 105215, 10.1016/j.ssci.2021.105215
- [8] Wang H.-R., Chen Q.-G., Yan J.-B., Yuan Z., Liang D., Emergency guidance evacuation in fire scene based on pathfinder, *Proceedings - 7th International Conference on Intelligent Computation Technology and Automation, ICICTA 2014 (2015)*, pp. 226-230, 10.1109/ICICTA.2014.62

- [9] Ferscha A., Zia K. LifeBelt: Crowd evacuation based on vibro-tactile guidance, *IEEE Pervasive Comput.*, 9 (2010), pp. 33-42, 10.1109/MPRV.2010.83
- [10] EN ISO 7010:2020, Graphical symbols - Safety colours and safety signs - Registered safety signs.
- [11] Lazaros Filippidis, Hui Xie, Edwin R. Galea, Peter J. Lawrence, Exploring the potential effectiveness of dynamic and static emergency exit signage in complex spaces through simulation, *Fire Safety Journal*, Volume 125, 2021, 103404, ISSN 0379-7112, <https://doi.org/10.1016/j.firesaf.2021.103404>.
- [12] AMATECH, <http://www.amatech.eu/systemy-i-oprawy-oswietlenia-awaryjnego/dynamiczny-system-kierowania-ewakuacja/dynamiczny-system-kierowania-ewakuacj%C4%85-dke-szczegoly>, 5.04.2023
- [13] K. Kowalski, Analysis of evacuation methods and strategies from public facilities, Engineering thesis, Engineering thesis, SGSP 2021
- [14] Council Directive 92/58/EEC of 24 June 1992 on the Minimum Requirements for the Provision of Safety And/or Health Signs at Work, 1992.
- [15] Health and Safety (Safety Signs and Signals) Regulations 1996 (SI No. 1996/341), The Stationery Office: London, ISBN 978-0-11-054093-1.
- [16] G. Weisman, Orientation, path finding, and architectural legibility: a review and theoretical integration, in: *Proceedings of the International Conference on Building Use and Safety Technology*, NIBS, 1985, pp. 9 – 15.
- [17] P. Arthur, R. Passini, *Wayfinding: people, signs and architecture*, 1992, pp. 76 – 81, 0-07-551016-2.
- [18] H. Xie, L. Filippidis, E.R. Galea, D. Blackshields, P. Lawrence, Experimental analysis of the effectiveness of emergency signage and its implementation in evacuation simulation, *Fire Mater.* 36 (2012) pp367 – 382, <https://doi.org/10.1002/fam.1095>.
- [19] W. Grosshandler, N. Bryner, D. Madrzykowski, K. Kuntz, Report of the technical investigation of the station nightclub fire, NIST NCSTAR 2. 2005.
- [20] T.J. Shields, K.E. Boyce, A study of evacuation from large retail stores, *Fire Saf. J.* 35 (1) (2000) 25 – 49, [https://doi.org/10.1016/S0379-7112\(00\)00013-8](https://doi.org/10.1016/S0379-7112(00)00013-8)
- [21] Gyuyeob Jeon & Wonhwa Hong (2009) Characteristic Features of the Behavior and Perception of Evacuees from the Daegu Subway Fire and Safety Measures in an Underground Fire, *Journal of Asian Architecture and Building Engineering*, 8:2, 415-422, DOI: 10.3130/jaabe.8.415