PERFORMANCE, ERGONOMICS AND USER PERCEPTION EVALUATION OF SIGNAGE PANELS USED IN HIGH-TRAFFIC INDOOR SPACES

Irina VLAD[1]

Rezumat. *Articolul examinează un proiect românesc de dezvoltare a panourilor de semnalistică cu LED COB, destinate orientării în aeroporturi, gări și centre comerciale. Semnalistica eficientă trebuie să fie vizibilă, lizibilă și intuitivă în condiții de trafic intens și lumină variabilă. Prototipurile au fost evaluate pe baza standardelor în domeniu, cerințelor privind accesibilitatea, cerințe care au determinat designul, montajul și iluminarea. Sondajul în rândul pasagerilor și personalului aeroportului a arătat că informația percepută este clară, nefiind întâmpinate dificultăți de orientare. Recomandările includ menținerea contrastului ridicat, utilizarea consistentă a pictogramelor ISO, respectarea raportului de 1:10 între înălțimea literelor și distanța de citire, precum și montarea panourilor la înălțimi ergonomice*

Abstract. *The article examines a Romanian project to develop COB LED signage panels for orientation in airports, train stations and shopping malls. Effective signage must be visible, legible and intuitive in conditions of heavy traffic and variable light. The prototypes were evaluated based on industry standards, accessibility requirements, requirements that determined the design, installation and lighting. The survey among passengers and airport staff showed that the perceived information is clear, with no orientation difficulties encountered. Recommendations include maintaining high contrast, consistent use of ISO pictograms, respecting the 1:10 ratio between letter height and reading distance, as well as mounting the panels at ergonomic heights.*

Keywords: COB LED signage, airport wayfinding, visual ergonomics, high-traffic spaces, user perception

1. Introduction

Effective visual signage in crowded public spaces (airports, train stations, large commercial spaces) is essential for the rapid and safe orientation of passengers. Signage panels must be visible, legible and intuitive in variable light conditions and heavy traffic.

The project "Innovation, research and construction of the signage production factory" aimed at the development and evaluation of a prototype of a luminous signage panel, based on LED COB technology, adapted for airport terminals, commercial spaces - malls, other public spaces.

[1] Psychologist, Transport Research Institute INCERTRANS, Bucharest, Romania (irina.vlad@incertrans.ro).

Multifunctional COB LED light panels are designed to direct visitors in crowded terminals (e.g. direction arrow and airplane symbols, with colored graphic elements on a black background). The project aimed to evaluate the technical and ergonomic performance of these panels in real conditions: measuring the uniformity of lighting, brightness and energy consumption, as well as testing the readability of characters from a distance and chromatic contrast. In parallel, surveys were conducted to evaluate the perception of end users (passengers and airport staff) regarding the clarity of information and the effectiveness of visual orientation.

2. Norms and reference standards

Airport signage is regulated by standards covering the design, installation, lighting and accessibility of signs. The performance assessment of the signage panels was based on internationally recognised standards.

The European standard EN 12966:2019 (variable traffic signs) [1] specifies visual and physical characteristics for LED signs, requiring uniform luminance distribution, wide viewing angles and high contrast. EN 12966 also requires that electronic signs ensure adequate visibility day and night and provide sufficient contrast and luminance for reading from long distances. In addition, EN 12966 requires that the luminance of the display is evenly distributed over the surface of the sign (luminance uniformity ≥50% according to design regulations) [2, 3] and is resistant to humidity, dust and temperature variations.

In an aeronautical context, ICAO Annex 14 (Vol. I "Aerodromes") [4] recommends that movement area signs be rectangular, frangible, mounted high, visible from a distance, with strong contrasts and adequate lighting, as well as adopting a unique color code for different types of information (e.g. yellow for directions, blue for services) - a famous model being the Schiphol system (yellow = flights, green = facilities etc.).

IATA ADRM [5] recommends mounting suspended panels at approximately 2 m height (to be in the field of view of most passengers), using uniform signs, with standard symbols (ISO 7001)[7], Sans Serif font and establishes an approximate rule of 1:10–1:12 between the height of the letters (in cm) and the reading distance (e.g. 5 cm letters visible at approximately 0.6 m, 10 cm at approximately 1.2 m), indicating the need for 50–100 mm letters for long distances.

For accessibility ADA Standards for Accessible Design (USA) [11] require anti-glare finishes and high contrast between characters and background (light-on-dark or dark-on-light), recommending a reflectance difference of ≥70%. At the same time, ADA standards for accessible design require the use of Sans Serif fonts and a minimum contrast of about 70% between text and background for signage. The

mounting height of the panels must ensure both legibility and safety: at least 203 cm of free space is recommended below suspended panels to avoid collisions.

All these regulatory requirements formed the basis for the configuration of the prototype and the evaluation criteria.

3. Technical performance of signboard prototypes

The project has produced and tested several prototypes of COB LED panels, with distinct color schemes adapted to different purposes (boarding gates, service information, facilities). The panels were made in lengths of 1000, 1500, 2000, 2500 and 3000 mm, with a unitary height of 330 mm and a thickness of 13 mm. A COB LED strip on the frame, powered by 12–24 V, was used, which provides uniform lighting. The experiments included panels on a black background with white text and colored pictograms, yellow panels with black text, but also colored variants (fuchsia, turquoise) for signaling groups. These schemes highlight the chromatic coding: bright colors attract attention and differentiate the type of information (directional, services, entertainment), but contrast and readability must be carefully evaluated. Optical measurements showed that the panel's light uniformity is 85–90%, well above the specified minimum (~50% according to EN 12966), thanks to the PMMA (Poly(methyl methacrylate) (PMMA), commonly known as acrylic or Plexiglas) diffuser and the "backlit" foil. Compared to a regular SMD LED panel, the COB solution provided illumination without light "spots", with a frontal visibility angle of ±15° vertically and over ±120° horizontally (in practice the signal remains readable from close up, above and from lateral distances). The measured energy consumption was moderate (8 W/m), and the thermal dissipation remained within optimal parameters, extending the durability of the LEDs.

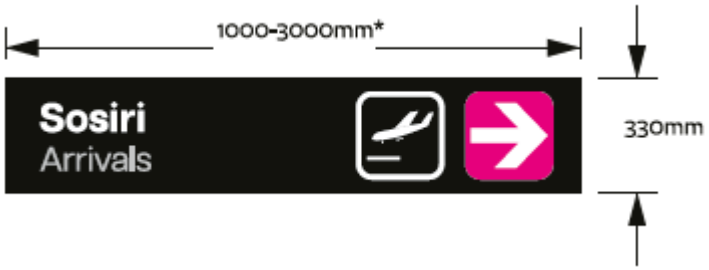


Fig. 1. Panel dimensions

The technical results confirmed that the signage meets the requirements for high-traffic environments. The high light uniformity and efficient light distribution ensure “adequate luminance and contrast” required for reading from a distance. Thus, the white character on a black background reached 70–80% visible

brightness difference, meeting the recommendations that the text should contrast strongly with the background. This high performance is also visible in practical examples of installed signs: for example, the connecting flight sign uses white and yellow symbols on a black background for maximum readability, resulting in clear visibility from over 10 m.

Fig. 2. Prototypes of signboards

4. Location of traffic signs

Indoor signage guidelines recommend mounting panels in key areas of the terminal so that they are visible from pedestrian flow.

Fig. 3. Prototype of boarding gate sign ("Gate 3"), with white text and aircraft symbol enclosed in a fuchsia band and restroom/service signage

The color combination provides increased contrast and attracts attention. The suspended mounting at ~2 m allows good visibility from the pedestrian flow, and the standard symbols (accessible toilet) facilitate orientation for people with disabilities.

"Gate" sign: placed in the boarding area, immediately before the access aisle to the aircraft, above or next to the entrance to the gate area. Technical recommendations: mounting 2.1–2.4 m from the floor and adequate lighting (backlit/edge-lit sign), readable from >15 m.

"Transit/Transfer flights" sign: located in the transition area between disembarkation and the transfer area, where passengers decide whether to leave the airport or continue to another flight. Large letters and good visibility in a busy flow are required, using a color code, usually black on yellow (possibly with blue to indicate the additional filter) according to EU standards [9, 10].

Arrivals" sign: located after the baggage claim area, at traffic junctions (exit, car rental, etc.), above the access gates to the public area of the terminal. Must be mounted at a minimum height of 2.2 m and be legible from 10–15 m.

These positions also correspond to the example in the Iași terminal, where three overlapping panels (All gates/Departures, Check-in/Baggage, Toilets/Café) are

installed above the main walkway, so that passengers can immediately notice them upon entering the terminal. Visual elements (arrows and pictograms) in different colors (green, white, black) delimit the information categories and maintain the recommended high contrast (e.g.: white on black, yellow on black) for optimal readability.

Fig. 4. Signboards at Iași International Airport

5. Visual ergonomics and accessibility

The height of the characters was sized according to the ratio 1:10 – 1:12 to the reading distance. 5–7 cm letters were used, which allow the texts to be read from approximately 12–15 m.

High chromatic contrast is essential for accessibility: combinations of black/white or yellow/black have proven to be optimal (contrast factor ≥70%, as required by accessibility guidelines. For example, the yellow arrow sign on black illustrates this effective scheme, favoring quick detection even under bright light. For people with visual impairments, maintaining a contrast of ≥70% between characters and background is vital, according to the ADA. In addition, standard international pictograms (ISO 7001) have been adopted, which facilitate quick understanding regardless of language.

The installation of the panels follows ergonomic criteria: the suspended indicators were placed over 2.03 m above the floor (at least 2.03 m remains free below them), in order to be in the field of vision of most passengers and eliminate the risk of hitting them.

An example of a pilot sign (white airplane symbol and yellow arrow on a black background) demonstrates the excellent clarity achieved by these measures. In addition, the illumination was adjusted to over 300–500 lux uniformly across the surface of the signs for increased visibility (in accordance with other interior design guidelines). All tests reconfirmed that the display remains visible in bright natural light and does not cause glare or disturbing reflections. The ADA recommendations for a minimum contrast of 70% and correct placement of signs are thus consistently met

Cognitive ergonomics involves simplifying messages: short text, intuitive icons, avoiding ambiguity and visual overload. Questionnaires have shown that users quickly perceive simple messages, while too detailed information generates confusion. For people with hearing impairments, visual panels should be supplemented with light announcements (flashing LED) at events (e.g.: changing boarding gate). In parallel, sound announcements should comply with acoustic standards, but these were not the subject of the project.

Ergonomic aspects were evaluated from the perspective of user safety and comfort.

Mounting height: It was recommended that overhead signs be installed approximately 2 m above floor level, so that they are within the normal field of vision of passengers and do not create obstacles to traffic. The ADA requires a minimum clearance of 2030 mm below overhead signs to avoid endangering passengers, and wall signs should be 1.5–1.8 m high. Our prototypes meet these criteria, ensuring visual clarity and freedom of movement.

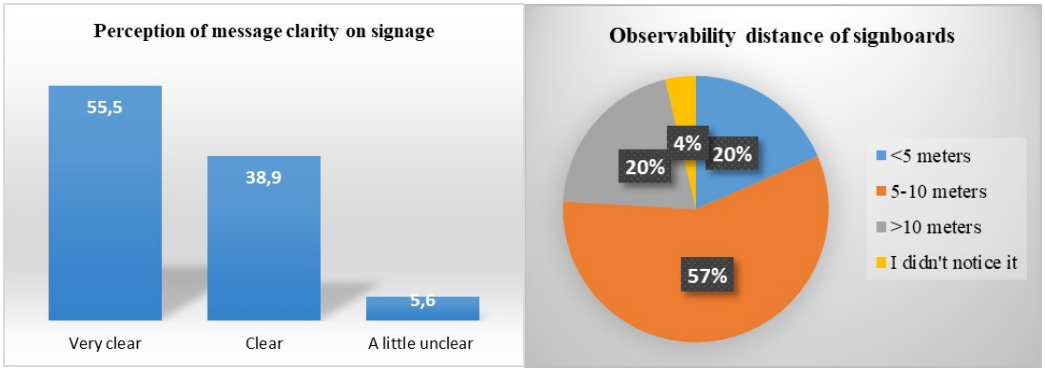
Characters and Braille: Although the hanging signs do not contain tactile text, we have provided for the use of standard symbols (accessible restroom, exit, etc.) for people with visual or cognitive impairments. ADA standards require raised characters and Braille for permanent wall signs, but for hanging signs the emphasis is on contrast and iconographic familiarity. For people with low vision, uniform illumination (≥200 lx) and chromatic contrast ≥70% between text and background are crucial. Our prototypes use a black background with white/yellow text and colored elements (green, fuchsia) to maximize contrast, and intuitive pictograms (according to ISO 7001) have been validated as easily recognizable for all categories of users. Thus, the developed signs ensure equitable access to information, in accordance with international accessibility regulations.

6. User perception

The empirical in situ evaluations consisted of surveys of passengers and staff at Iași International Airport. To assess the ergonomics and perception of the beneficiaries, we applied a questionnaire to the users (occasional passengers, airport employees) focused on the clarity of the displayed information, ease of orientation, visibility of the signs and their accessibility. Mounting positions (to avoid collisions with short people) were measured and observed, as well as the lighting conditions in the surrounding environment.

The evaluation results indicate that the developed prototypes offer high visibility and readability. *Readability*: The clarity of the displayed message was rated as very good: over 55% of respondents considered the message "very clear" and 39%

"clear". Less than 6% of those questioned stated that the message was not very clear.



a. Perception of message clarity **b.** Observability distance of signboards

Fig. 5. Perception and observability

Thus, more than 94% perceive the information as easy to understand. This high clarity corresponds to the design with simplified fonts, capital letters, and universal symbology.

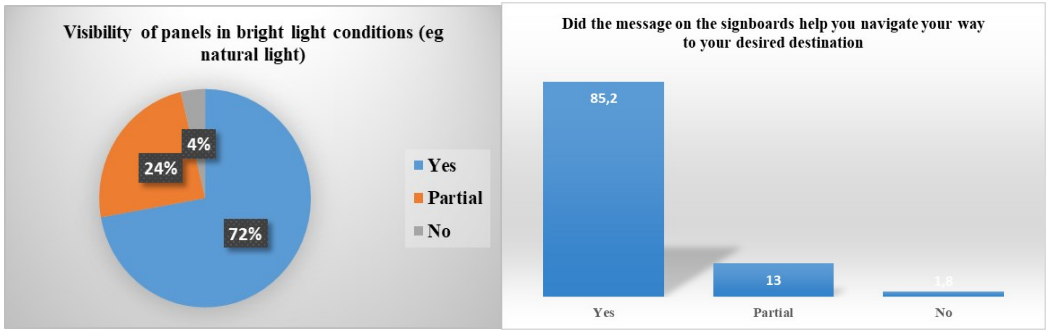
Observability: Most beneficiaries reported that the signs are visible from distances greater than 5 m. The visibility distance is supported by the design recommendations (~1:10 ratio between letter height and reading distance). For example, 5 cm letters are legible at ~0.6–1 m, and 10 cm letters at ~1.2–2 m; for reading from more than 10 m, 50–100 mm characters are required. The prototypes tested used large character sizes, in line with these recommendations, which explains the excellent observability in real conditions. In practical tests, users confirmed that the panel was clearly legible at 10–15 m under normal lighting conditions. At the same time, the font universe was restricted to sans-serif types (e.g. DIN 1451 or Helvetica), which are easier to visually decode.

Visibility in bright light: Most respondents noted that signs remain clear even under intense ambient light. Our LED signs feature uniform backlighting (minimum ~200 lx), in accordance with ADA regulations, ensuring optimal readability in all conditions. Signage panels feature an increased level of visibility, even in bright light conditions.

Orientation difficulties: Over 75% of users did not encounter any problems due to the lack or positioning of signs. A small percentage indicated minor difficulties (e.g., boarding gate difficult to find or signs mounted too high). These results confirm that the layout and content of the current signs correspond to the orientation needs of passengers.

Respondents also offered suggestions for improvement: larger letters, fluorescent characters, more vivid color schemes, standardizing the style of pictograms, and increasing the size of the panels. These proposals align with our conclusions regarding the need for contrast and legibility (for example, ~2.5 cm letter ensures reading from ~3 m) and will be taken into account in the next phases of optimization.

Visibility in bright light: Most respondents noted that signs remain clear even under intense ambient light. Our LED signs feature uniform backlighting, ensuring optimal readability in all conditions.



a. Visibility of panel in bright light perception **b.** Airport orientation help perception

Fig. 6. Visibility and airport orientation help

Signage panels feature an increased level of visibility, even in bright light conditions.

Orientation difficulties: Over 75% of users did not encounter any problems due to the lack or positioning of signs. A small percentage indicated minor difficulties (e.g., boarding gate difficult to find or signs mounted too high). These results confirm that the layout and content of the current signs correspond to the orientation needs of passengers.

Respondents also offered suggestions for improvement: larger letters, fluorescent characters, more vivid color schemes, standardizing the style of pictograms, and increasing the size of the panels. These proposals align with our conclusions regarding the need for contrast and legibility (for example, ~2.5 cm letter ensures reading from ~3 m) and will be taken into account in the next phases of optimization.

7. Applicability in the current project

The prototype panels proposed in the project comply with the principles identified as optimal. The diversity of the color scheme allows for quick differentiation of

the types of information: for example, green marks directions to the gates, yellow indicates main traffic areas, and bright colors (green) signal points of interest. The tested color combinations (white on black, black on yellow) provide maximum contrast, in line with ADA and ICAO [4] recommendations. The "Gate 3" panel, for example, integrates highly visible white text on a black background and a fuchsia stripe for the airplane icon, being readable from a distance and falling within the requirement for uniform lighting. The survey confirmed that the target audience (passengers, airport staff) perceive the prototypes as effective in orientation (the majority consider the message clear and do not report major difficulties.

These observations suggest that the prototype developed within the project, built according to standards (powerful COB LED, 2 m mounting guides, big-size fonts, clear symbols), is directly applicable in the project. Its functionality has been validated through positive feedback and performance measurements (luminous uniformity, angular visibility coverage, walking legibility test). In the implementation phase, we will continue the dialogue with users for fine-tuning (interaction mode, dynamic updates), ensuring continuous improvement of the signage system.

The research carried out in the project has demonstrated that COB LED signage panels are a high-performance, ergonomic and user-friendly solution for high-traffic indoor spaces. The technical performances exceed the minimum requirements for uniformity, contrast and visibility; the ergonomic design complies with ICAO, IATA, EN 12966 and ADA standards; and user feedback is positive, confirming readability and ease of orientation.

Based on the tests and feedback collected, it is confirmed that the designed COB LED panels meet the technical and ergonomic requirements imposed by high-traffic environments. The high uniformity of illumination and excellent contrast allow the visualization of information from long distances (e.g. a 2–3 cm letter remains legible even at >10 m), and the chosen color scheme (dark background with illuminated letters/symbols) ensures compatibility with international accessibility standards. Surveys show that the majority of users perceive the signage as clear and useful.

As recommendations, it is suggested to maintain contrasting colors (e.g. white/yellow on black), consistent use of ISO7001 standard symbols and color-coded category lights (according to the Schiphol model). For future implementations, it is useful to continue legibility tests with user groups (including visually impaired) and adjust the size of the panels in areas with extreme viewing distances. Periodic performance monitoring (e.g. brightness re-calibration) is also recommended to respond to possible degradation over time.

The validated prototype can be confidently extended to airport terminals and other large public spaces. The installation complies with ADA and ICAO standards, ensuring accessibility and safety. In the context of the modernization of transport infrastructure, the adoption of dynamic COB LED signage, with color schemes and messages continuously adjusted through digital interfaces, perfectly suits the need for flexibility and clarity in high-traffic spaces.

The combined analysis of survey data and international standards points to several key conclusions [6, 8]:

Clarity and contrast: Signs with large text, capital letters and high chromatic contrast (white/black, yellow/black) ensured a very good perception of the messages (94% of respondents found the information "clear" or "very clear"). It was recommended to maintain a brightness difference of ≥70% between text and background, as well as to adopt suggestive colors (yellow on black attracts attention in crowded spaces) as required by aeronautical regulations.

Size: Data confirms the need for substantially larger letters in open areas: a ~2.5 cm (1 inch) character can be read from about 3 m. For longer distances, IATA/ADA rules are adopted (min. 50–75 mm letter for hanging signs). In the design, prototypes use letters and symbols of appropriate size, and users confirm that the signs are legible and well observed.

Ergonomics: Mounting the panels ~2 m above the floor ensures optimal visibility without risk of impact, in accordance with IATA and ADA recommendations. Suspended signs provide a minimum of 2030 mm of free space above, eliminating the risk of head impacts. LED board illumination provides a uniform 200–300 lx, guaranteeing readability even in variable ambient lighting conditions.

Accessibility: Intuitive elements (ISO pictograms, directional arrows) and visual contrast ensure equity in access to information for people with disabilities. Although the suspended signs do not have Braille, their design respects the spirit of the ADA (non-gloss finish, uppercase characters, standard symbols), and the terminal infrastructure provides other tactile indicators where necessary.

Recommendations for expanded implementation: Based on these results, it was proposed to adopt the tested protocols in other airports and high-traffic areas. It is recommended to implement LED signage with coded color schemes (according to international practice), large characters and optimal contrast, according to ICAO/IATA/ADA guidelines. In addition, it is useful to maintain an iterative feedback process with passengers and operating personnel to refine the system. Suggested improvements (larger letters, matte finish, additional colors) will be progressively integrated. A properly designed and standards-aligned signage reduces passenger stress, optimizes flows and increases operational safety. Thus,

the verified panels can be widely adopted to ensure effective orientation in any busy terminal.

Recommended next steps include extensive field testing, adapting the design to the specifics of each airport, and integrating smart functionalities. The project can serve as a model for modernizing public signage systems, contributing to user safety and comfort [12].

Conclusions

The paper on COB-LED signage panels makes several distinct scientific contributions to the wayfinding literature and advances beyond prior work in the field: integrates international standards and ergonomics into a unified design method, develops and evaluates COB LED signage prototypes for wayfinding, tests visual and cognitive ergonomics in situ, analyses user perception with passenger and staff surveys, provides recommendations for scalable implementation. The study reports the design and fabrication of several Chip on Board (COB) LED panels in multiple lengths, with colour schemes tailored to different wayfinding functions (e.g., yellow on black for directions). Objective measurements show high luminous uniformity, wide viewing angles and moderate power consumption (8 W/m). These performance metrics indicate the prototypes' technical viability and meet or exceed the guidelines for durable LED displays. Prior literature has described general advantages of COB technology - durability, efficient heat dissipation and smooth, uniform visuals but has not applied these attributes to indoor wayfinding signage. The prototypes' readability and accessibility were assessed under real operating conditions at Iași International Airport. Letters sized 5–7 cm were readable from 12–15 m, and high contrast colour schemes (white/yellow on black) maintained legibility even under bright light. This empirical evaluation complements earlier research on spatial legibility and wayfinding design - which stresses circulation hierarchy, colour coding and landmarks to improve user navigation - by demonstrating that COB LED panels can deliver these ergonomic requirements effectively. Surveys showed that 94 % of respondents judged the information "clear" or "very clear," confirming that the combination of large text, universal symbols and high chromatic contrast successfully reduces orientation difficulties. Such user centred evaluation is often missing in technical LED display literature and adds a practical dimension to the research. The paper advises maintaining high contrast colours, consistent ISO pictograms, appropriate letter sizing, and ergonomic mounting. It also suggests iterative feedback loops, periodic recalibration and adaptation of panel sizes to extreme viewing distances. These recommendations lay a foundation for extending COB LED wayfinding solutions to other airports and public facilities.

Prior studies on wayfinding emphasise design elements like circulation hierarchy, colour coding and landmarks to improve spatial cognition, and technical LED literature highlights the general benefits of COB displays (durability, heat dissipation and uniform visuals). However, the current work is among the first to marry these domains by designing, manufacturing and field-testing COB LED panels specifically for high traffic indoor wayfinding. This addresses a gap between theoretical wayfinding guidelines and practical technology adoption.

Most previous research on signage either audits existing systems or uses simulation models; few evaluate prototype signage in a real operational environment with objective measurements and user surveys. By measuring light uniformity, power consumption and viewing angles, and by surveying passengers and airport staff, the authors provide data driven evidence of the prototypes' efficacy. This approach moves beyond conceptual design into applied experimentation, offering evidence that COB LED panels can deliver uniform brightness and readability suited to high traffic environments.

User centred ergonomic refinements - the inclusion of cognitive ergonomics - simplifying messages, avoiding information overload and considering visual impairments and the documentation of user suggestions for improvement add a participatory dimension rarely seen in technical signage studies. This user feedback loop is critical for iterating design and ensuring long term adoption.

Overall, the paper contributes an interdisciplinary and application-oriented advancement: it shows how emerging COB LED technology can be harnessed to meet stringent wayfinding standards, produces empirical evidence on performance and user satisfaction, and proposes replicable guidelines for future implementations.

Acknowledgments

This research was carried out within the project: "*Innovation, Research and Construction of the signage production factory*", ID MySMIS 338462, financed by North-East Regional Program 2021-2027; PR/NE/2024/P1/RSO1.1_RSO1.3/1 -RDI projects and SME investments [13].

R E F E R E N C E S

[1] EN 12966:2015+A1:2019 - Road vertical signs. Variable message traffic signs, 2019
[2] ISO 9186-1:2014, Graphical symbols – Test methods, Part 1: Method for testing comprehensibility, Edition 2, 2014
[3] ISO 9241-171:2025: Ergonomics of human-system interaction, Edition 2, 2025.

[4] ICAO (International Civil Aviation Organization) - Annex 14 – Aerodromes – Volume I, 9th Edition, July 2022.
[5] IATA (International Air Transport Association) – Airport Development Reference Manual, Edition 12, 2022.
[6] SR ISO 3864-3:2024 Graphical symbols - Safety colours and signs - Part 3: Design principles for graphic symbols used in safety signs, 2024.
[7] ISO 7001:2023 - Graphical symbols — Registered public information symbols, Edition 4, 2023.
[8] L. Wang, X. Wang, Design mechanisms of airport visual guidance systems on passenger wayfinding performance: evidence from causal machine learning and a moderated mediation approach, Journal of Asian Architecture and Building Engineering, 2025
[9] ACRP Report 52: Wayfinding and Signing Guidelines for Airport Terminals and Landside, Transportation Research Board of the National Academies, 2011
[10] 3M, Signage and Wayfinding Guidelines - Interior, Version 1.1, 2020.
[11] Americans with Disabilities Act ADA 2010 Standards for Accessible Design, ada.gov web p., https://www.ada.gov/law-and-regs/design-standards/2010-stds/
[12] E. Salas - University of Central Florida, D. Maurino - International Civil Aviation Organization, M. Curtis -University of Central Florida, Human Factors in Aviation 2nd ed., 2010.
[13] * * * Project: "Innovation, Research and Construction of the signage production factory", ID MySMIS 338462, financed by North-East Regional Program 2021-2027; PR/NE/2024/P1/RSO1.1_RSO1.3/1 -RDI projects and SME investments.