

Optimising Safety Way Guidance Systems with a Graphical Tool. Application in a subject of a Master's Degree in Occupational Health and Safety

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Abstract. This article delineates an innovative educational approach within the Master's in Occupational Risk Prevention at the University of Zaragoza, focusing on optimal evacuation route signage through a practical class session. The class emphasizes the significance of effective signage, pivotal for guiding occupants safely during emergencies. The curriculum integrates theoretical knowledge with hands-on applications, employing both manual and digital tools to enhance learning outcomes. Students engage in the direct application of safety standards and signage optimization, initially working manually and subsequently utilizing a custom-developed graphical tool, SignCirCAD, integrated with AutoCAD. This tool simplifies the visualization and modification of signage coverage areas, enabling efficient design adjustments without extensive AutoCAD experience. The session's structure includes theoretical instruction, practical exercises, and the application of the graphical tool, culminating in a project where students optimize real-world signage within our university's Agustín de Betancourt building. By bridging theory with practical skill application, the program not only reinforces understanding but also equips students with the essential competencies for effective emergency management in occupational settings. The findings suggest that the graphical tool significantly enhances signage coverage with minimal increase in sign numbers, demonstrating its effectiveness in optimizing evacuation signs in compliance with safety standards.

Keywords: Safety Way Guidance Systems, Occupational Risk Prevention, Graphical Tool.

1 Introduction

Within the context of advanced training in Occupational Health and Safety, this article describes an innovative learning experience implemented with students from the University Master's in Occupational Risk Prevention (MUPRL). This experience is cen-

tered around a practical class designed to teach students the optimal signage of evacuation routes in buildings, a crucial element in emergency management that guides people to safe exits in critical situations.

Before addressing the specific contents taught in the class, the importance of analysing the effectiveness of the implemented signage is reviewed. Various studies have highlighted the relevance of the coverage area of the signs [1,2] and the conditions affecting their visibility, such as smoke in case of fires [3], thus underscoring the need to adapt the signs to the dynamic conditions of an emergency. In this regard, dynamic signage systems have been proposed that adjust instructions in real-time as the danger situation evolves, which can be independent [4-6] or linked with BIM systems [7, 8]. These systems can optimize evacuation times and reduce congestion and travel distances, resulting in more efficient evacuations compared to static signage systems.

For the development of the class, the focus is on the use of static signs, which are the basis of all improvements reviewed in previous studies. Additionally, the class references the European Council Directive 92/58/EEC [9] and the Spanish Technical Building Code [10], which mandates compliance with the UNE 23034 standard [11]. This standard references international norms ISO 7010 [12] and ISO 3864-1 [13].

Regarding the practical application of theoretical knowledge, the use of specific tools is addressed. Despite the existence of various software applications for signage evacuation routes [8, 14], these often require a high learning curve and are not always accessible to all users. Therefore, the use of SignCirCAD [15], a graphical tool that integrates with AutoCAD to allow simplified use, is chosen. This tool is ideal for students who are not familiar with reading building plans or using computer-aided design software.

The session is structured into a theoretical part where students learn the basic principles of signage. Subsequently, students apply this knowledge in a practical exercise. Initially, they manually place the evacuation signs of the ground floor of the building where they are located; later, they use SignCirCAD to transfer and optimize their design in the digital environment of AutoCAD, which allows verification of the improvements in the designed signage. We believe this methodology not only reinforces theoretical understanding but also develops practical skills crucial for effective emergency management in work environments.

2 Methodological Description

The training session has been carried out for several years, within the context of the course "Specialty in Workplace Safety", which is part of the Master's Degree in Occupational Risk Prevention at the University of Zaragoza. The objective is to apply the knowledge acquired by the students in the correct safety signage of the Agustín de Betancourt building at the university.

Initially, students are provided with a theoretical foundation that includes relevant legal frameworks (Directive 92/58/EEC [9]) and relevant standards (ISO 16069 [16], ISO 3864 [13]). After the explanation, the faculty address some practical problems re-

lated to safety signage. This preparatory stage is designed to ensure all participants understand the fundamental principles and regulatory requirements before moving on to practical application.

Students participating in this practice have the option to utilize all types of market-available safety signs. In accordance with the mandatory UNE 23034 standard [11], as stipulated by the Código Técnico de la Edificación [10], these signs are available in three sizes, visible from 10, 20, and 30 meters. However, the latter two sizes are not recommended due to their large dimensions. Additionally, the signs come in three formats: flat, panoramic, and wall-perpendicular, as illustrated in **Fig. 1**.

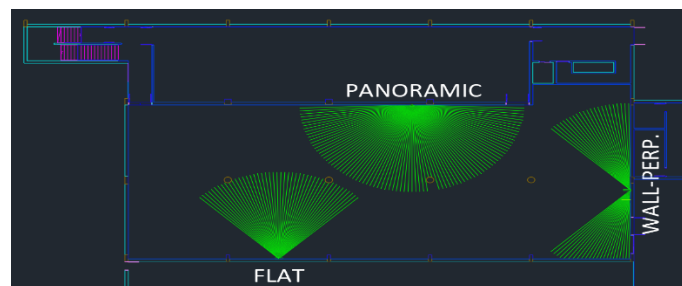


Fig. 1. Example of the three types of signs, with 10-meter visibility, drawn in the Study Room, which measures 45 x 18 meters.

Following the theoretical stage, students take a guided tour of the Agustín de Betancourt building. This allows the participants to directly observe the spatial distribution and assess the specific signage needs of the building on-site.

The students are provided with the ground floor plan of the building printed on ISO A3 paper at a 1:750 scale, as shown in **Fig. 2**. During the tour, students are asked to identify and mark the existing safety signage on the plan. This practical exercise aims to familiarize them with the real environment and the current safety implementations.

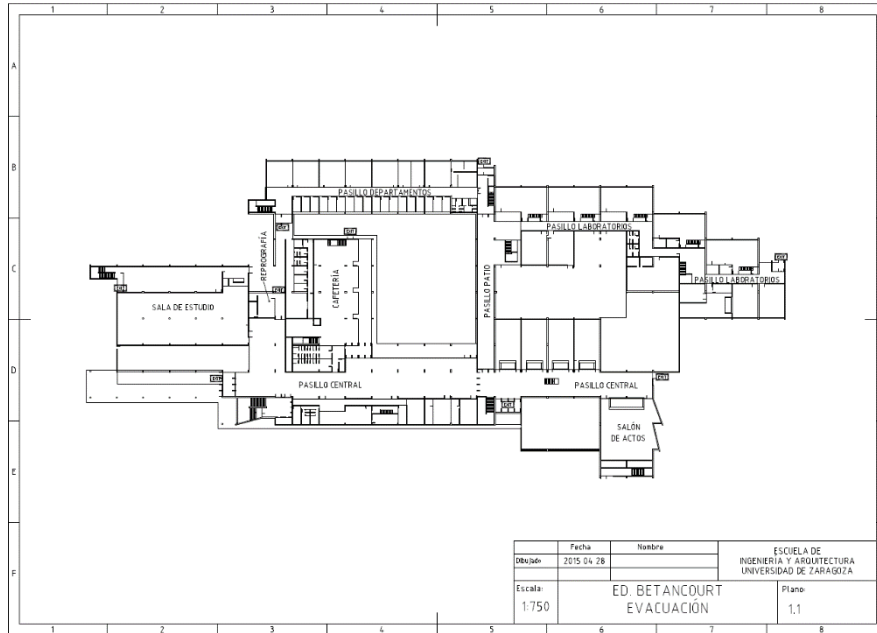


Fig. 2. Ground floor plan of the Agustín de Betancourt building

Additionally, students are challenged to propose improvements in the signage based on their critical analysis and acquired knowledge. This aspect of the exercise aims to stimulate analytical thinking and the practical application of their skills in a realistic context, allowing them to propose the modifications they consider pertinent to optimize the evacuation and safety signage of the building.

Once the students have completed the manual signage task on the plan, as seen in **Fig. 3**, an advanced graphical tool, specifically designed to replicate and optimize such signage is explained [10]. This tool is an application that works on AutoCAD.

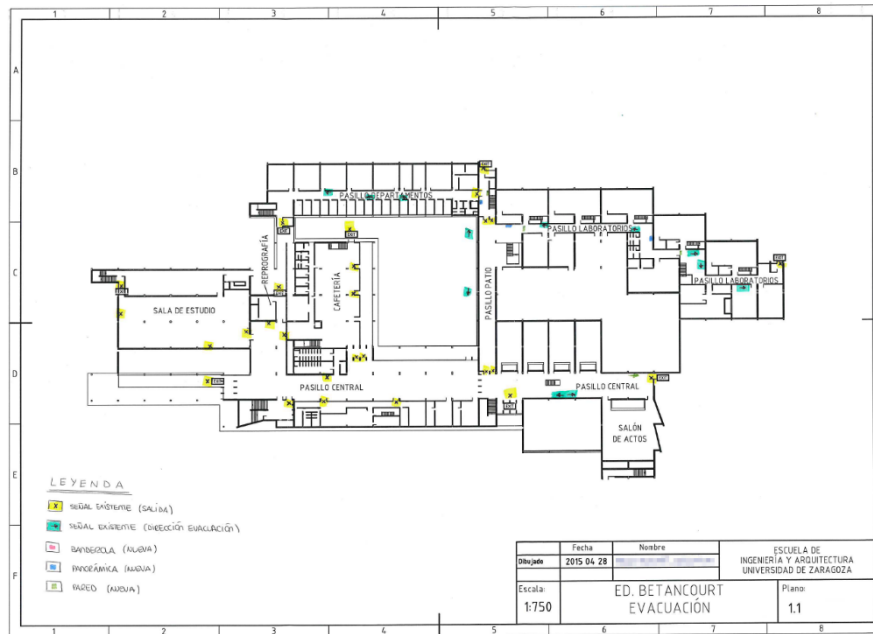


Fig. 3. Example of initial design done manually on the plan

The main functionality of this graphical tool allows students to clearly visualize the coverage areas of the signs on the plan. Furthermore, it offers the capability to automatically calculate the total area covered by the inserted signs, thus providing precise and valuable data for the analysis and improvement of safety signage.

As a practical application of the explanation, students are proposed to transcribe the signage design they have manually created into the digital environment using the graphical tool. To facilitate the practical exercise, the lecturers provide students with the building's blueprint as an AutoCAD drawing.

This activity allows them to correctly visualize the area covered by the inserted signs, highlighting the blind and overlapping areas existing in the signage they have produced, as seen in **Fig. 4**.

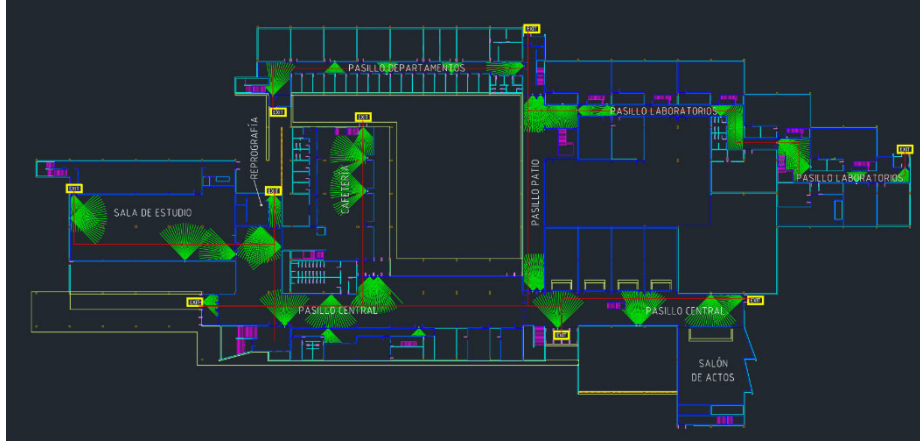


Fig. 4. Example of initial design, once transferred to AutoCAD using the graphical tool

To conclude the exercise, students are challenged to optimize the building's signage using the graphical tool. They are asked to try to maximize the coverage area of the signs without significantly increasing the installation cost. One of the exercises can be seen in **Fig. 5**.



Fig. 5. Example of optimized design from the previous plan in **Fig. 4**

Students can calculate the coverage area of their new installation whenever they consider appropriate, as shown in the % column of **Fig. 6**, comparing it to the manual design they previously created, as seen in **Fig. 7**.

Zona	%	Sup. Zona	Area Cubierta	Señales	Sup. Bruta	Sup. Islas	Nº Islas
25. LABORATORIO 25	26,38	157,8	41,6	1	157,8	0	0
26. LABORATORIO 26	25,55	162,8	41,6	1	162,8	0	0
27. LABORATORIO 27	25,56	162,8	41,6	1	162,8	0	0
29. LABORATORIO 29	24,5	163,1	40	1	163,1	0	0
30. LABORATORIO 30	47,64	100,2	47,7	1	100,2	0	0
33. ZONA 6	47,14	99,7	47	1	99,7	0	0
7. PASILLO SECRETARIA	64,18	98,6	63,3	3	98,6	0	0
CAFETERÍA	52,62	584,3	307,5	5	585,4	1,1	5
ENTRADA PRINCIPAL	72,98	35,3	25,8	2	35,3	0	0
ESCALERAS BIBLIOTECA HYPATIA	91,24	75,9	69,3	1	75,9	0	0
PASILLO CENTRAL	82,11	1712	1405,7	29	1719	7	9
PASILLO DEPARTAMENTOS	86,63	266,8	231,1	11	266,8	0	0
PASILLO LABORATORIOS ZONA 2	88,51	102,1	90,4	5	102,1	0	0
PASILLO PATIO	66,55	402,5	267,8	6	402,5	0	0
PASILLOS LABORATORIOS ZONA 1	96,63	291	281,2	12	291	0	0
REPROGRAFIA	27,92	104,5	29,2	1	104,5	0	0
SALA DE ESTUDIO	85,77	810,3	695	6	811,6	1,3	4
SALIDA DEPARTAMENTOS	31,96	13,6	4,3	1	13,6	0	0
SALIDA TRASERA	66,62	65	43,3	3	65	0	0
SALON DE ACTOS	28,56	390,9	111,6	2	390,9	0	0

Fig. 6. Screenshot of the table with the data on areas from the optimized version

Zona	%	Sup. Zona	Area Cubierta	Señales	Sup. Bruta	Sup. Islas	Nº Islas
7. PASILLO SECRETARIA	17,25	98,6	17	2	98,6	0	0
CAFETERÍA	26,8	584,3	156,6	3	585,4	1,1	5
ENTRADA PRINCIPAL	43,41	35,3	15,3	1	35,3	0	0
PASILLO CENTRAL	32,73	1712	560,4	11	1719	7	9
PASILLO DEPARTAMENTOS	38,46	266,8	102,6	5	266,8	0	0
PASILLO LABORATORIOS ZONA 2	20,21	102,1	20,6	2	102,1	0	0
PASILLO PATIO	39,84	402,5	160,4	5	402,5	0	0
PASILLOS LABORATORIOS ZONA 1	57,74	291	168	7	291	0	0
REPROGRAFIA	27,92	104,5	29,2	1	104,5	0	0
SALA DE ESTUDIO	27,76	810,3	224,9	4	811,6	1,3	4

Fig. 7. Screenshot of the table with the data from the initial version

The session ends with a group discussion where manual and optimized signage approaches using the graphical tool are compared. The results are analyzed, highlighting the advantages of graphical optimization in terms of coverage and cost.

The class is structured into a five-hour session, evenly divided among four distinct segments: a theoretical lecture, a guided building tour, instruction on graphical tool usage, and a practical design exercise using the tool to create both manual and optimized signage plans.

2.1 Building to be signposted during the exercise

The exercise involves marking the escape routes on the ground floor of the Agustín de Betancourt building at the University of Zaragoza.

Students are required to attempt signage of the entire floor; however, our analysis focuses specifically on three distinct areas highlighted in Fig. 6. These areas correspond to architectural features commonly found across many buildings requiring signage.

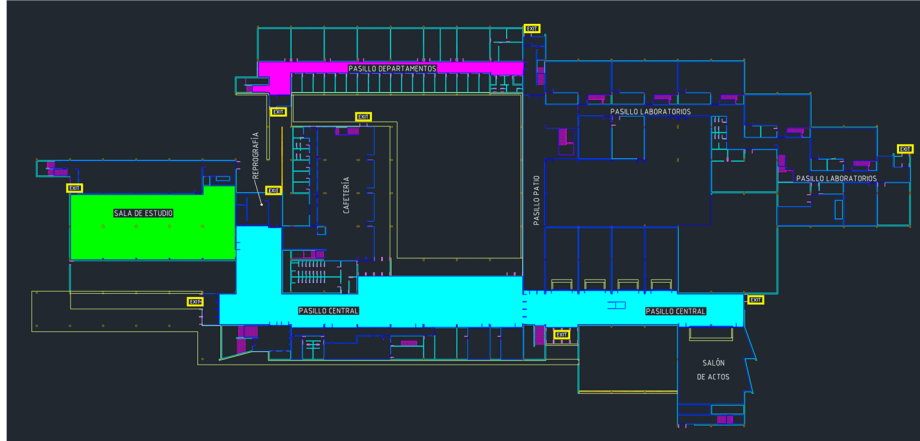


Fig. 8. Spaces to analyze

- Study room (Sala de estudios): green color. A room with two emergency exits, one at each end, with general dimensions of 45x18 meters and an area of about 812m².
- Department corridor (Pasillo de departamentos): magenta color. A corridor with an emergency exit at each end. The maximum length is 72 meters, with a width of 3m. The area it covers is 266m².
- Central corridor (Pasillo central): cyan color. Corridor with various emergency exits. The maximum length is 142 meters, Its width ranges from 9 to 14 meters and the area it covers is 1720m².

3 Results

In the session under review, a total of 14 students effectively participated, comprising seven females and seven males. The average age was 27.4 years (SD 4.25), with a range from 22 to 37 years. All participants were master's students from various backgrounds. Six had backgrounds in engineering or architecture, and only two had prior experience using AutoCAD in their professional or academic endeavors.

3.1 Coverage areas of the signs

The coverage area data for the signs inserted into the plans will be analyzed. These data are accessible in the tables generated by the application for each plan created by the students.

The statistical data from the manually created plans can be viewed in **Table 1**. Statistical data concerning the distribution of signs using the graphical tool are available in **Table 2**.

Table 1. Coverage area of the signs from the manual design.

Space	Mean	DS	Max. value	Min. Value
Pasillo Central	42,6	17,4	74,4	14,2
Pasillo Departamentos	50,2	13,8	74,2	28,8
Sala de Estudio	39,4	15,2	75,3	19,3

Table 2. Coverage area of the signs from the optimized design.

Space	Mean	DS	Max. value	Min. Value
Pasillo Central	76,0	8,0	88,6	61,5
Pasillo Departamentos	82,5	13,2	95,7	52,6
Sala de Estudio	76,7	12,2	95,7	47,5

3.2 Number of signs inserted in the plans

The analysis of the number of signs used in the signage is also found interesting.

First, we can see the statistical data on the number of signs used in the manually signed plans in **Table 3**, and the data from the plans signed with the graphical tool in **Table 4**.

Table 3. Number of signs inserted in the manually signed plans

Space	Mean	DS	Max. value	Min. Value
Pasillo Central	10,2	4,1	19,0	4,0
Pasillo Departamentos	4,4	1,3	6,0	2,0
Sala de Estudio	3,9	1,3	6,0	2,0

Table 4. Number of signs inserted in the plans signed using the graphical tool

Space	Mean	DS	Max. value	Min. Value
Pasillo Central	15,7	5,2	29,0	10,0
Pasillo Departamentos	5,6	2,0	11,0	3,0
Sala de Estudio	5,4	1,2	8,0	4,0

4 Discussion

This analysis focuses on the results obtained from the signage practice using AutoCAD, considering the students' limited prior experience with this software and architectural plan reading. Although only two out of fourteen students had previous experience with AutoCAD, and only half were familiar with reading plans, all participants were able to complete the practice and significantly improve the initial manual design.

The graphical tool used proved to be a key facilitator in this process, significantly reducing the AutoCAD learning curve. For the students, it was sufficient to know how to adjust the plan's display scale and how to select and delete objects. The insertion of the signs and the automatic calculation of the coverage area were effectively managed by the graphical tool, significantly simplifying the process.

Upon analyzing the data on coverage areas, a considerable increase was observed in the optimized version of the design: the Central Hallway showed an increase of 78.6%, the Department Hallway 64.5%, and the Study Room an impressive 94.5%. This increase not only reflects an improvement in the students' ability to optimize signage but also demonstrates the effectiveness of the graphical tool in maximizing coverage while minimizing effort and resources employed.

Additionally, a significant improvement was noted in the minimum coverage value among the students, moving from a range of 14%-29% in the manual design to a range of 48%-61% in the optimized design. This represents an improvement of between 82% and 300%, ensuring that even in the worst cases, coverage improved substantially.

The analysis of the number of signs used revealed an increase in the optimized version: 53.8% for the Central Hallway, 25.8% for the Department Hallway, and 38.2% for the Study Room. When comparing this increase with the rise in coverage area, it is evident that the efficiency of the signage improved significantly, thus meeting the objective of maximizing coverage with the least number of signs possible.

These results underline the importance of integrating advanced graphical tools in the teaching of safety signage, enabling students to effectively apply their theoretical knowledge in a practical and realistic context. Furthermore, they highlight the capability of the graphical tool to facilitate complex technical learning in an accessible and efficient format.

5 Conclusions

The lack of familiarity with interpreting plans and the unfamiliarity with AutoCAD or other CAD programs for working with plans should not be barriers to learning about the signage of evacuation routes in buildings. The developed graphical tool facilitates the acquisition of necessary skills to efficiently signpost a building.

Although the lecturers provide the graphical tool free of charge for student assignments, its use is not mandatory. Signage can also be manually performed in AutoCAD, although this requires a deeper understanding of the program and a greater investment of time.

The design of the signage coverage area is crucial to blind and overlapping areas. Additionally, calculating the total covered area allows for the comparison of different signage solutions. It is generally assumed that greater coverage area implies more effective signage as it facilitates the orientation of users within the building.

Moreover, it is important to note that the graphical tool allows for the adjustment of the dimensions and shapes of the coverage areas, which could facilitate the analysis

of signage installations to adapt them to individuals with limitations in the perception of signs, as recommended by the ISO 16069 standard.

6 Future Work

The study focuses on optimizing evacuation route signage in a specific building at the University. This may limit the generalization of the results to other industrial settings, as safety conditions and requirements can vary significantly between different building types and sectors. Future research should aim to apply these optimization techniques to various building types and industrial environments. Conducting similar studies in different contexts will help validate the findings and adapt the methods to diverse safety needs.

Further development of the application is planned so that it can verify whether the distribution of the signs complies with the ISO 16069 standard recommendations or, at least, provide some guidelines for signage.

It is also relevant to focus on the overlap of the coverage areas of the signs. According to the standard, this overlap may cause confusion among the building users.

Finally, it will also be necessary to update the graphical tool to represent the coverage area with reduction factors depending on the user's viewing angle. This new factor was defined in the 2023 revision of the UNE 23034 standard, which was published after the exercise was conducted.

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