EGE–Revista de Expresión Gráfica en la Edificación, Nº 21, 2024. ISSN: 2605-082X
https://doi.org/10.4995/ege.2024.22997
APEGA, UPV

GRAPHIC STANDARDS FOR THE DESIGN OF SPACES IN HIGH-SPEED RAILWAY STATIONS

Juan Bautista Font Torres [a], Jorge Luís García Valldecabres [b], Luís Cortés Meseguer [c]

[a] Programa de Doctorado en Arquitectura, Edificación, Patrimonio y Ciudad, Universitat Politècnica de València, Spain.
[b] Centre for Research on Architecture, Heritage, and Sustainable Development Management PEGASO, Universitat Politècnica de València, Spain.
[c] Department of Architectural Constructions. Universitat Politècnica de València, Spain.
[a] juafont1@doctor.upv.es, [b] jgvallde@ega.upv.es, [b] luicorme@upv.es

Abstract

The liberalisation of passenger transport by rail on high-speed lines has produced a turning point in this mode of transport. The access of new private railway companies has led to an increase in the number of passengers using this means of transport. This situation has repercussions on the existing stations because the spaces initially designed are not capable of absorbing this new increase and the future demand. This problem can be seen in the València Joaquín Sorolla station. The station was conceived as a provisional station until the construction of the tunnel under the city, but the provisional nature of the station has been prolonged, creating the need to extend the station to absorb the demand for new passengers until the works are completed. However, this increase in demand has had a negative impact on the initial design of the station and on the planned extension, which has been overwhelmed by this growth. In this article, the aim is to qualify graphically the state of deterioration of quality and safety for users of this type of public service as a preliminary step for the study and definition of standards capable of guaranteeing the design in terms of safety and comfort to respond to the new demand.

Keywords: passengers flows, comfort, liberalisation, quality, demand.

*Correspondence author: Juan Bautista Font Torres, juafont1@doctor.upv.es
Received: 7 December 2024, Accepted: 19 December 2024, Published: 31 December 2024

1. INTRODUCTION

The arrival of the liberalisation of the high-speed rail system entails a change in the station model, both in terms of the needs and the planning of their use. In this sense, many of the large pre-existing stations do not have the capacity to accommodate these new needs, which is why new stations are being built or extended. The new stations are located on the urban periphery, away from the consolidated centre, but normally located close to what are considered potential new centralities, such as a new residential or business area. In addition to this new location, their design and functionality changes, becoming not only passenger interchange spaces, but also offices, shopping centres, hotels, convention centres, car parks and, in short, large spaces for economic use.

This change in the location, design and use of the station also brings with it new social relations and a new way of seeing the station for the public. However, the liberalisation of the High Speed in Spain and the consequent appearance of new railway companies (October-December 2022), has led to an increase in the number of passengers using this type of service. The 'provisional' station, inaugurated in December 2010, will be extended because it is unable to meet the needs of passengers while work on the new access canal to the city and its underground central station is completed.

In the literature there are case studies on pedestrian flows in light rail and metro stations in Hong Kong (Lam et al., 1999), train stations in Lisbon (Hoogendoorn et al., 2004) in these cases the use of rail access facilities or their level of service is considered. Earlier studies focused on pedestrian crossing areas, such as pedestrian pavements, developing models and theories, such as crowd theory, to describe and simulate movement processes (Fruin, 1971).

As studies focused on facilities affecting a station, there is an exposition on how the width of stairs affects the speed of pedestrian flow and how bi-directional pedestrian movement affects the capacity of undivided stairs located in rail transit stations (Jiten et al., 2016).

Recently, some researchers focussed on the effects of different environments and facilities on pedestrian movements using 'level of service' (LOS). An example of LOS application is the one used in metro station research whereby the flow of travellers is optimised by improving the service provided (Zhang et al., 2017).

Figure 1. Urban barrier produced by the train tracks at València Estació del Nord station. Source: (IDOM, 2008).

The planned extension of the station in this study includes walkways, waiting areas and platforms and, in a broader sense, all passenger spaces within a railway station. These facilities are a focus of attention as pedestrian congestion is becoming a common phenomenon (Ganansia et al., 2014) and station platform and concourse areas are becoming scarcer (Hoogendoorn et al., 2004) creating interferences in terms of comfort and safety (Nio, 2012).

2. THE OBJECT OF STUDY

València Joaquín Sorolla station is a 'terminal' type station. Unlike 'Pass-through' stations, which are those in which the railway line or lines enter on one side and leave on the other, so that trains can pass through the station, the sack-bottom stations are usually the terminals of the lines, the trains always enter on one side of the station and leave again on the same side, as they cannot continue beyond it. As a station conceived as provisional, it is designed as a simple covering of platforms - two 230 m long platforms and one 400 m long platform giving access to six tracks - with a common space in front of them as a public space for arrivals and departures. The covering itself is extended and separated from the horizontal plane to form a relationship space.

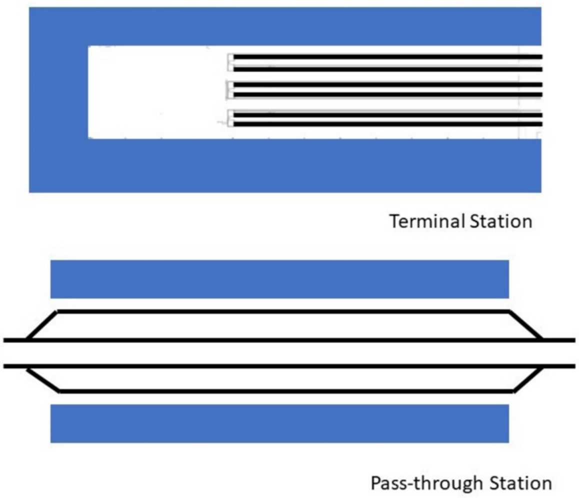


Figure 2. Type of stations. Source: Authors.

The building is resolved in its entirety from a single formal idea as an element with a different scale. The roof of the platforms is extended and raised to define the space of the lobbies.

The uses of the station such as customer service, offices and railway services are installed under the protective roof by means of a block connection. In the concourse area, the linear elements are joined together by skylights at different levels to allow natural lighting and ventilation of the open-plan space. The concept is based on modularity. The main structure is defined by a repetition of modules formed by metallic steel profiles and polycarbonate panels for covering and closing the façade (IDOM, 2008).The Figure 3 shows the passenger transit areas and the surface areas occupied.

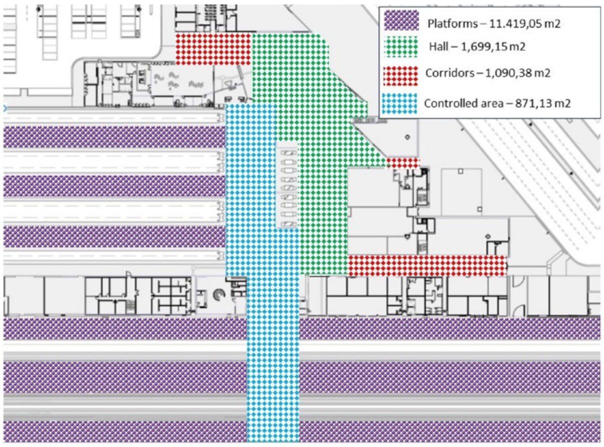


Figure 3. Passenger Transit areas and surface. Source: Authors based on (INECO, S.A., 2022).

The liberalisation of the high-speed market has led to an increase in passengers on the Madrid-Valencia corridor (Comisión Nacional de los Mercados y la Competencia , 2º Trimestre 2024), as defined in the Figure 4, which shows by quarter and operating companies.

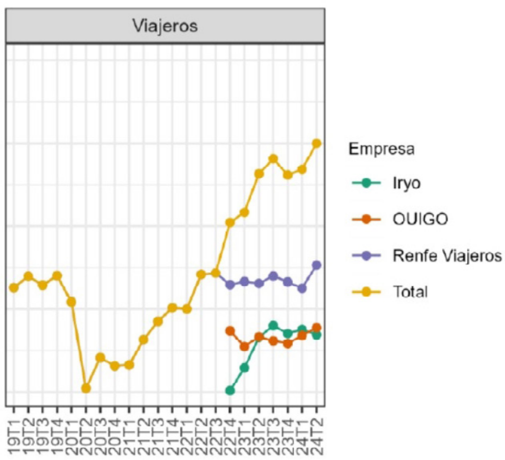


Figure 4. Evolution of passengers by quarter and company. Source: CNMC 2024.

Figure 5. Infographic of the planned extension of the station. Source: (INECO, S.A., 2022).

Because of this increase in passenger numbers, a solution was designed to provide the existing station with a larger surface area and an increase in the number of tracks (INECO, S.A., 2022) to absorb this increase.

The Figure 6 shows the blocks that currently make up the station (in red) and the planned actions (in blue). One of the actions to be carried out in the extension that directly affects passengers is the creation of an elevated concourse, connected to the existing concourse, equipped with vertical communication elements (stairs, escalators, and lifts) that will connect with the new tracks, as shown in the plan and infographics below The new concourse is raised above the tracks as a constructive solution to the lack of space in the boarding concourse.

Figure 7. Access and view of the elevated concourse. Source: (INECO, S.A., 2022).

3. OBJECTIVES

The extensions to existing railway stations due to the increase in the supply of services mean that the solutions adopted to absorb the increase in passengers may require significant expansions that the urban planning of the city where they are located cannot be carried out, as in the case of

Figure 6. Expansion of Valencia Joaquín Sorolla station and location of the elevated concourse. Source: (INECO, S.A., 2022).

the station under study. This is why it is necessary to define a protocol for the design of spaces for passengers as a starting point for calculating the capacity of the different areas that make up these railway infrastructures.

4. METHODOLOGY

The method used in the research is the mixed method (Pole, 2009), based on deductive comparative analyses from quantitative studies in which numerical information, periodicity, standards, averages are defined for the understanding of numerical information and to be able to establish dependencies and cause and effect relationships, making generalisations and testing or confirming theories, hypotheses, or assumptions by means of statistical analysis. In this way, the results are expressed in numbers or graphs, i.e. in quantitative research methods, allowing the establishment of standardised background screening protocols that can be used by others to endorse the study. Qualitative research involves collecting and analysing non-numerical data to understand concepts, opinions, or experiences. It provides a holistic orientation that brings together and studies descriptive background with deeper contextualised insights. It also allows for a comparison of the effects achieved from different origins (Conde, 1990). Exploration is driven by the same objective: to find patterns in the data they collect to establish a relationship between the elements. Both methodologies are essential to support existing theories and to develop new ones.

This takes into account all the spaces to be crossed (platform, stairs, concourse), waiting times in the station and a specific time at which there is the greatest influx of trains at the station (peak hour), which allows the maximum number of passengers to be obtained and which, based on the surface area of the areas under study, allows the level of service (LoS) to be determined according to (Fruin, 1971).

For the calculation of occupancy, the maximum occupancy value shall be taken throughout the day and in the period corresponding to the peak hour. The extent of the peak hour to be considered is set within the above interval being sensitive to the station's train service. The criterion used to calculate occupancy during the period considered is all trains that can enter or leave the station simultaneously and the trains following the previous ones, considering only passengers boarding. Occupancy depends on the timetables defined in the circulation grids, which include the stopping times, the peak time being obtained from the arrival and departure times. In terms of time in the station, this time is directly related to the type of customer.

In the case of users who are going to travel, they arrive in advance, a time called caution time, while in the case of travellers leaving the station, this time is dependent on factors such as the orientation within the station and the route taken by the traveller to leave the station. This caution time is composed of a safety time, produced by passengers anticipating possible delays during the journey to the station, a time used for orientation within the station itself and, if applicable, a time used for farewells to accompany persons. It is obvious that the precautionary time is dependent on the distance between the origin of the journey and the station and is related to the behaviour and psychology of the passengers themselves. This caution time is composed of a safety time, produced by passengers anticipating possible delays during the journey to the station, a time used for orientation within the station itself and, if applicable, a time used for farewells to accompany persons. It is obvious that the precautionary time is dependent on the distance between the origin of the journey and the station and is related to the behaviour and psychology of the passengers themselves. The Figure 8 shows the number of passengers depending on the caution time taken by users. In the case studied, the slope of the graph shows the increase in waiting passengers as we approach the minute when the train is announced (30 minutes before departure) and boarding begins. In these 30 minutes prior to the train's departure, the percentage of passengers reaches 90% of the seats occupied.

The determination of the number of users of the station provides the start of the process for the calculation of the capacity of the different elements that make up these infrastructures such as passageways, lobbies, access controls, platforms, etc. The calculation is based on the absorption capacity of these elements. The calculation is based on the absorption capacity of these elements.

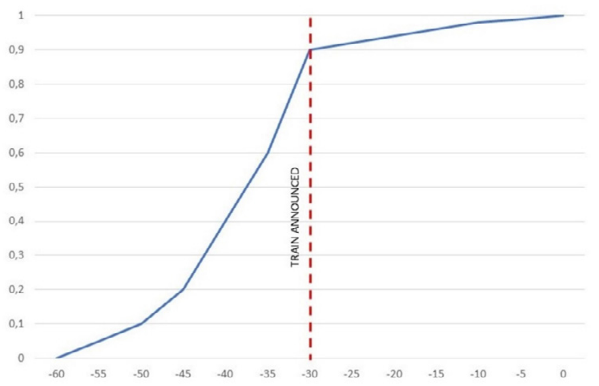
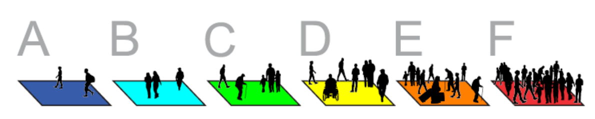


Fig 8. Arrival time and number of users at the station studied. Source: Authors.

This is why this absorption capacity will be determined as supply and the number of users who intend to pass through these areas will be determined as demand.

To determine the density of occupation, the method investigated by J.J. Fruin in the 1960s for pedestrian flows will be used (Fig. 9).



Level of Service (LoS)	Definition
A	Free circulation
B	Uni-directional flows
C	Sightly restricted circulation with difficulty passing others. Reverse and cross-flows with difficulty
D	Restricted circulation for most. Reverse and cross-flows with significant difficulty
E	Restricted circulation for all intermittent stoppages and serious difficulty for reverse and cross-flows
F	Complete breakdown of flow with frequent stoppages

Figure 9. Levels of service (LoS). Source: Authors based J.J. Fruin (1971).

The choice of this method is based on the volume/capacity ratio by means of which design levels are determined (six in total, between A and F) allowing a qualitative and quantitative design of the case study to be obtained.

The use of this method under normal conditions allows to obtain the appropriate levels of comfort in the areas occupied by passengers as well as the assessment of the maximum use of these areas.

Level of Service (LoS)	Surface	Density
	m²/passenger	passenger/m²
A	>3.24	<0.27
B	2.32-3.24	0.43-0.31
C	1.39-2.32	0.72-0.43
D	0.93-1.39	1.08-0.72
E	0.46-0.93	2.17-1.08
F	<0.46	>2.17

Figure 10. Levels of Service according to area occupied. Source: J.J. Fruin (1971).

5. DISCUSSION

The peak hour is obtained from the train timetables. In the case studied, we obtain the morning and afternoon peak hour, the hours with the highest number of trains running at the station and, consequently, the highest number of seats offered:

	Arrival	*Departure*	*From*	*To*	*Seats*
Morning Peak Hour		10:00	València JS	Madrid Chamartín	457
		10:06	València JS	Madrid Chamartín	509
	10:19		Burgos RM	València JS	353
	10:30	10:30	Barcelona Sants	Alacant Terminal	332
		10:35	València JS	Madrid Chamartín	353
	10:40		Madrid Chamartín	València JS	457
Afternoon Peak Hour		18:00	València JS	Madrid Chamartín	457
		18:01	València JS	Barcelona Sants	332
	18:19		Madrid Chamartín	València JS	353
	18:40		Madrid Chamartín	València JS	457
	18:42	18:42	Gijón / Xixón	Vinaròs	353
		18:45	València JS	Madrid Chamartín	353
	18:55	18:55	Alacant Terminal	Barcelona Sants	332

Figure 11. Peak times at the station. Source: Authors, based on ADIF data.

According to the Figure 11, the number of seats offered is 2461 in the morning peak hour and 2637 seats in the evening peak hour. To these seats must be added the seats offered during the hour following the peak hour as passengers will be arriving at the station as shown in Figure 8, resulting in 3250 and 3447 passengers at each peak hour respectively. Only the areas are analysed the concourse and the controlled area after the baggage check.

Area	Surface (m^2)	From 10:00 to 12:00 h	From 18:00 to 20:00 h
		m^2/passenger	
Concourse	1699.15	0.52	0.49
Controlled Area	871.13	0.26	0.25

Figure 12. Areas studied. Occupation per unit area. Source: Authors.

The levels of the zones occupied by the concourse and the controlled area obtained by passenger density reach occupancy levels E and F respectively, which does not favour the feeling of comfort and safety of passengers. These values are calculated in normal operation and would be increased in the event of emergency or degraded situations, reaching the point of collapsing the station and its accesses. Another point analysed is the routes travellers take through the station. The flows created by passengers with the arrival of a train increase the problems in terms of the movement of users through the station.

This situation leads to crossings and flow interchanges which affect the level of comfort and safety perceived by passengers. Train arrivals produce peaks in demand which affect throughput capacity as groups of passengers can cause congestion, a situation which increases in the event of degraded situations which cause delays in the departure and arrival of trains at the station.

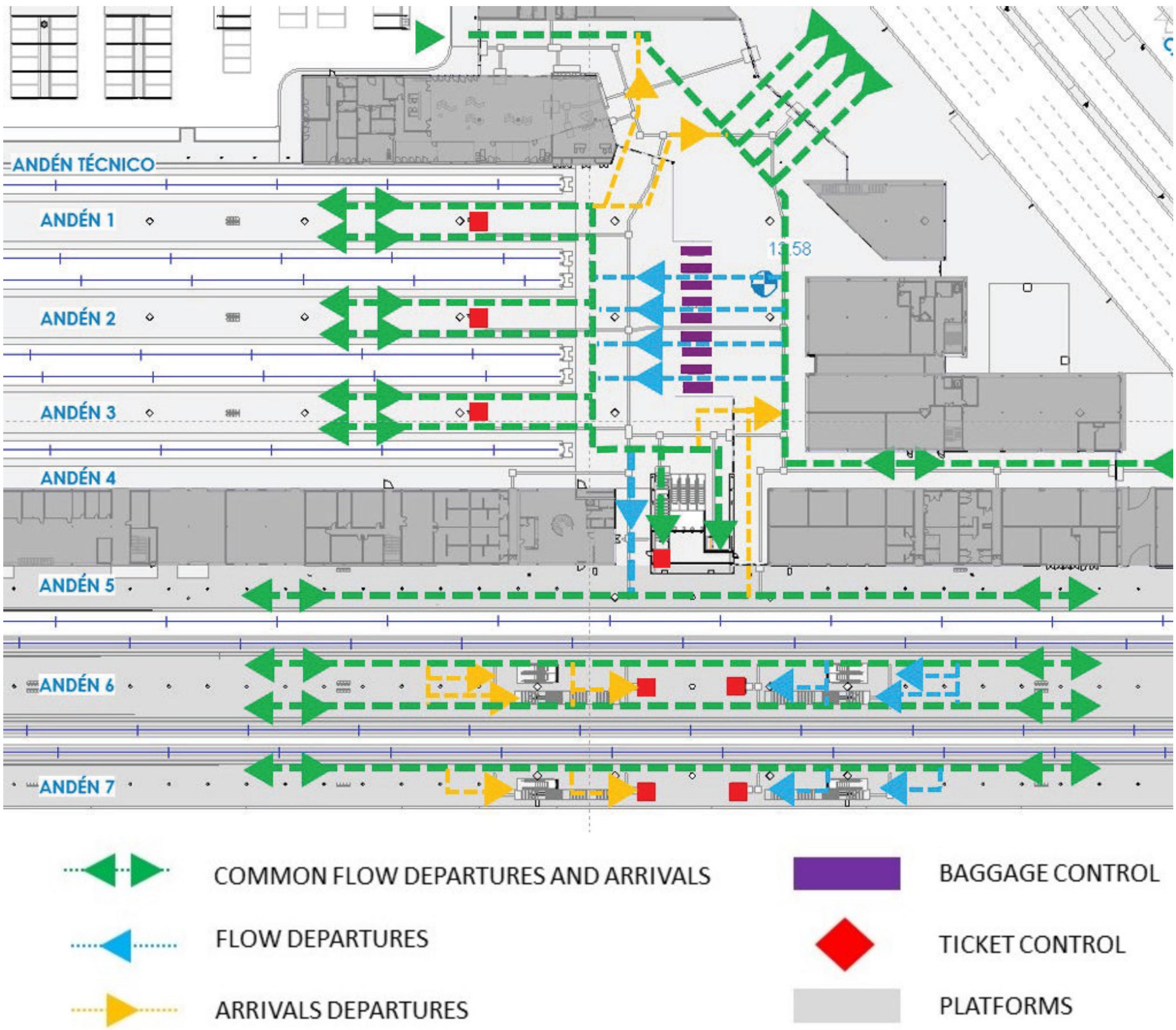


Fig 13. Passenger flows. Prepared by the authors based on (INECO, S.A., 2022).

The route taken by a passenger when getting off the train to the station exit is analysed. The trains used for the simulation are two trains with a capacity of 509 passengers each, taking their occupancy, the most unfavourable, to be 100%. The trains are parked on adjacent tracks. When a train arrives at the station, the first passengers take some time until the train leaves the station. This delay is due to the need to walk to reach these exits or due to a delay in the opening of the train doors after stopping.

Focusing on the first reason for delay, once passengers have alighted from the train, a steady flow is established, the magnitude of which is limited by the capacity of the exit.

As an example, we will study the route taken by a passenger, with no mobility restrictions, who arrives on a train parked on platform 7, the platform furthest from the exit (Fig. 13) and the exit door of the train is located at a distance of 10 m from the stairs leading to the elevated vestibule. The horizontal distance from the stairs leading to the elevated vestibule is 19 m.

The length of the elevated vestibule is 19 m. The length of the elevated vestibule is 40 m and the stairs leading down to the exit vestibule are 17 m horizontally. The distance between the exit vestibule and the door to the taxi area is 80 m. Based on studies carried out by (Weidmann, 1992) the I speed up the stairs is 0.610 m/s and the speed on flat surfaces is 1.34 m/s, the speed down the stairs is 0.694 m/s. With these data we obtain the average time necessary for the 509 passengers of the arriving train to reach the station exit:

$$\frac{10}{1.34}+\frac{19}{0.61}+\frac{40}{1.34}+\frac{19}{0.69}+\frac{80}{1.34}=\mathbf{2.15\ min}$$

This time of 18 minutes is the time taken by alighting passengers to leave the station. To simplify the calculation, it has been assumed that passengers have no mobility restrictions and travel with hand luggage.

6. RESULTS

Looking at the passenger flows at this station the size and number of exits influence the magnitude of the flow, with the flow tending to zero once

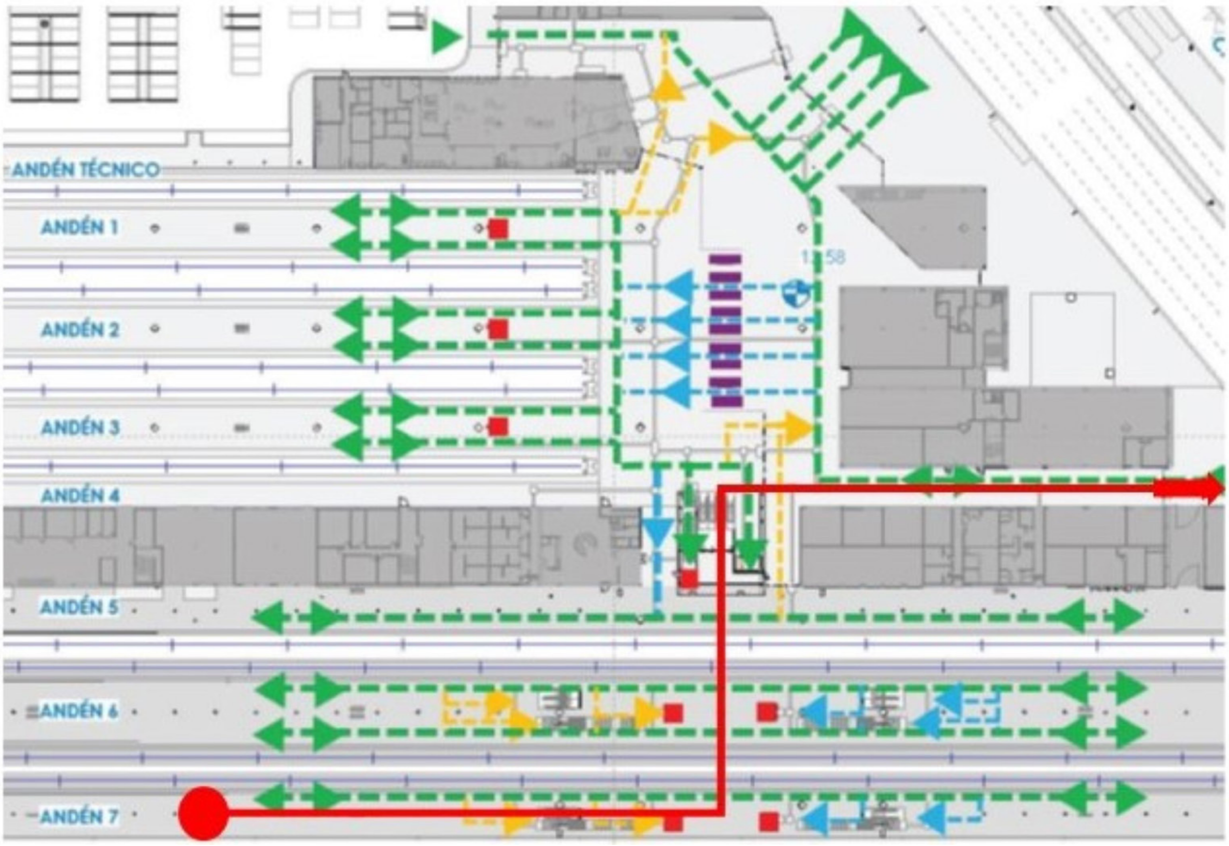


Fig 14. Journey of the analysed passenger. Source: Authors.

all passengers have left. This hypothesis demonstrates that the outbound tracks often represent the bottleneck in this situation (Benmoussa, 2011). In the example above, where an approximation of the time taken by a traveller is made, no 'counter-flow' or possible 'braiding' of passenger flows has been considered. These flows induced by the arrival and departure of trains have a negative impact on waiting areas and passageways making it necessary to have sufficiently large dimensions to facilitate the movement of passengers. This problem is partially present in through stations as passenger flows, depending on the arrival and departure of trains, can be easily separated but waiting areas or passageways can present congestion problems when flows coincide.

7. CONCLUSIONS

The necessary extensions to existing railway stations may require significant expansions that the urban planning of the city where they are located does not permit, as in the case of the station analysed. It should be remembered that the station analysed was built 'provisionally', so the two-level construction was ruled out from the beginning of the project phase.

The design of stations, even if they are provisional, must be adapted to offer a level of comfort and safety that is perceived by users. This is why there is a need for careful planning and sustained investment to ensure that railway stations can cope with growing passenger numbers.

The establishment of an optimal design is necessary, starting with the analysis of the hours of peak passenger traffic at the station. These hours coincide with the highest number of train arrivals and departures, thus beginning the process of calculating the surface areas required for the different areas that make up these infrastructures. This calculation is based on the absorption capacity of these elements, the supply being determined as the absorption capacity and the demand as the flow of users who intend to pass through these areas.

This is why it is necessary to define a protocol for the design of passenger areas in railway stations to meet the needs of users in terms of comfort and perceived safety.

REFERENCES

Augé, M. 1993. Los "no lugares": Espacios del anonimato, una antropología de la sobre modernidad. Barcelona: GEDISA. ISBN:84-7432 -459-9.

Benmoussa, M. 2011. Analyse des flux piétonniers en gare de Laussane. s.l.:Tech. Rep., Ecole Polytechnique Fédérale de Lausanne.

Comisión Nacional de los Mercados y la Competencia , 2º Trimestre 2024. Informe Trimestral: Transporte de viajeros por ferrocarril, Madrid: Subdirección de Análisis de Mercados - Dirección de Transporte y Sector Postal. https://www.cnmc.es

Conde, F. 1990. Un ensayo de articulación de las perspectivas cuantitativas y cualitativa en la investigación social. Revistas Española de Investigaciones Sociológicas, Issue 51, pp. 91-117. https://doi.org/10.5477/cis/reis.51.91

Fernández, R., Seriani, S., & Romero, H. 2014. Estudio experimental del efecto de medidas de gestión de flujos peatonales en los tiempos de subida y bajada de pasajeros en sistemas de metro. *XVIII Congreso Panamericano de Ingeniería de Tránsito, Transporte y Logística*, PANAM 2014.

Fruin, J. J. 1971. Designing for pedestrian: A level of service concept. New York: The Port of New York Authority.Higway Research Record.

Ganansia, F., Carincotte, C., Descamps, A., & Chaudy, C. 2014. A promising approach to people flow assessment in railway stations using standard CCTV networks. Transport Research Arena. Conference: Transport Research Arena (TRA) *5th Conference: Transport Solutions from Research to Deployment*. París.

Hermant, L. 2012. *Video Data Collection Method for Pedestrian Movement Variables & Development of a Pedestrian Spatial Parameters Simulation Model for Railway Station Environments*. s.l.:Tesis doctoral, University of Stellenbosch. https://api.semanticscholar.org/CorpusID:109570409

Hoogendoorn, S. P., & Bovy, P. H. 2004. Pedestrian route-choice and activity scheduling theory and models. *Transp. Res. Part B: Methodol*, Issue 38, pp. 160-190. https://doi.org/10.1016/S0191-2615(03)00007-9

IDOM, 2008. Proyecto Constructivo Red arterial ferroviaria de Valencia. Canal de Acceso. Acceso provisional ancho UIC. Madrid: Ministerio de Fomento - Secretaría de Estado de Infraestructuras.

INECO, S.A. 2022. Proyecto de construcción para ampliación y remodelación de la estación de Valencia Joaquín Sorolla. Madrid: Administrador de Infraestructuras Ferroviarias (ADIF Alta Velocidad).

INECO, S.A. 2023. Proyecto actuaciones necesarias estudio informativo del nuevo complejo ferroviqario de la estación de Atocha (Madrid): ADIF (Alta Velocidad). Madrid: s.n.

Jiten, S., Gaurang, J., Purnima, P., & Arkatkar, S. 2016. Effect of Stairway Width on Pedestrian Flow Characteristics at Railway Stations. *The International Journal of Transportation Research, 8*, pp. 98-112. https://doi.org/10.1179/1942787515Y.0000000012.

Kim, J. & Kim, Y. 2023. Analysis of Pedestrian Behaviors in Subway Station Using Agent-Based Model: Case of Gangnam Station, Seoul, Korea. *Buildings MDPI*, pp. 1-17. https://doi.org/10.3390/buildings13020537

Lam, W. H., Cheung, C. Y., & Lam, C. F. 1999. A study of crowding effects at the Hong Kong light rail transit stations. *Transp. Res. Part A: Policy Pract. 33*, pp. 401-415. https://doi.org/10.1016/S0965-8564(98)00050-0

Nio, I. 2012. *Het station als publieke ruimte*. Amsterdam: Tech. Rep., Bureau Spoorbouwmeester. https://issuu.com/bureauspoorbouwmeester/docs/14_08_12_sb-essay3-hetstationalspubliekeruimte

Pole, K. 2009. Diseño de metodologías mixtas. Una revisión de las estrategias para combinar metodologías cuantitativas y cualitativas. *Renglones. Revista arbitrada en ciencias sociales y humanidades. ITESO*, Issue 60. http://hdl.handle.net/11117/252

Weidmann, U. 1992. *Transporttechnik der Fussgänger - Transporttechnische Eigenschaften des Fussgängerverkehrs*. Zurich: Institut für Verkehrsplanung, Transporttechnik, Strassen- und Eisenbahnbau (IVT).

Zhang, Z., Jia, L., Qin, Y., & Yun, T. 2017. Optimization-based feedback control of passenger flow in subway stations for improving level of service. *Transportation Letters-the International Journal Of Transportation*, pp. 1-12.

How to cite this article: Font Torres, J.B., García Valldecabres, J.L., & Cortés Meseguer, L. 2024. "Graphic standards for the design of spaces in high-speed railway stations. the case of Valencia Joaquín Sorolla". *EGE Revista de Expresión Gráfica en la Edificación*, No. 21, Valencia: Universitat Politécnica de València. pp. 133-142. https://doi.org/10.4995/ege.2024.22997.