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Application of the 3D laser scanner for the analysis of hospital routes in terms of universal accessibility

This research proposes the use of laser scanners to analyse the conditions and characteristics of transit spaces in the vicinity of hospitals, from the perspective of universal accessibility and the integration of vulnerable people. To this end, we use the Hospital Universitario Príncipe de Asturias (Alcalá de Henares, Madrid) as a case study and we continue previous research consisting of the detection of the most important routes that occur in its urban environment and which have served to locate the most stressed spaces in which to develop this work. Through the use of the scanner and its treatment by means of different applied software, we developed a methodological process that allows us to treat, analyse and expose the problems detected in these spaces. With this, we can point out and manage different layers of information that are especially relevant from the accessibility point of view, such as changes in pavement, its width, ramp slopes, lighting, vegetation, etc., all with the precision offered by this digitalisation tool. Likewise, the graphic apparatus developed allows the results to be displayed in an inclusive way to facilitate their understanding by all users, regardless of their training; all of which contributes to facilitating possible actions to improve the accessibility of hospital environments.

Keywords:
Accessibility; inclusion; methodology; points clouds; routes

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1. INTRODUCTION

The aim of this research project is to detect those spaces and elements that hinder the integration of vulnerable people in hospital environments according to the different disabilities considered today and, all of this, as a means to improve the equality and inclusiveness of all users (UN, 2006). The project is organised in three distinct phases: firstly, the detection of flows and main routes taken by patients attending a hospital centre; secondly, and based on this initial work, the classification and analysis of the existing architectural barriers within these routes, as well as the spaces that can cause problems for the movement of vulnerable people; and finally, the proposals for the improvement of these elements.
The research presented in this article corresponds to the second phase of the project and builds on the previous work carried out during the first stage to detect the stressed spaces that could be studied in greater depth. Specifically, the research carried out during the first phase analysed and represented the routes to be followed by the different types of users according to their disability and at all scales: from their home to the surgery. Likewise, the time sequence necessary to complete these routes according to their disabilities has been studied, as well as the main architectural barriers that these users must overcome; all of which constitutes a first approximation to the object of study and the support for the detection of the specific areas of work for this second stage. In this sense, it is worth mentioning the work carried out inside the hospital (Domínguez et al., 2023) and in its surroundings (Gutiérrez et al., 2024), which serve as a preamble to the research presented in this article.
Due to the large architectural and urban scale addressed, as well as the spatial complexity, the type of representation used is based on the use of the diagram as a means for the didactic and inclusive transmission of the results, moving away from a vision of greater technicality that would hinder the comprehensive understanding of all people, regardless of their training: health

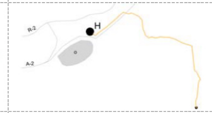
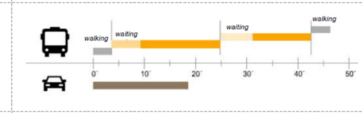
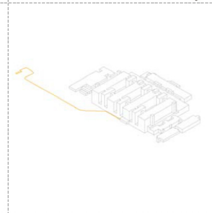
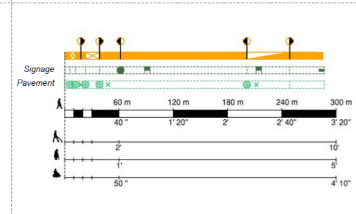
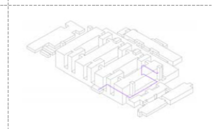
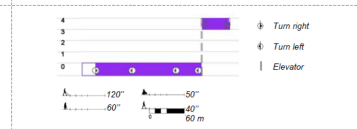
	Methodology	Graphic annalysis	Variables studied	Results
XL scale *territory scale*	• Documentation (public cartography, public transportation information) • 2D CAD diagrams		• Journey time according to the mode of transportation • Number and mode of public transport used	
L scale *urban environment*	• Documentation (official cartography documentation) • Field survey • 2D CAD diagrams • 3D CAD diagrams		• Journey time according to the functional diversity of each user • Number of turns in the journey • Number of intersections with vehicular traffic • Type of pavement (tactile, smooth, without pavement) • Visual signage	
M scale *building interior*	• Documentation (official hospital plans). • Field survey • 2D CAD diagrams • 3D CAD diagrams		• Journey time according to the functional diversity of each user • Number of turns in the journey • Number of vertical communication elements used.	

Fig. 1: Summary of the methodology used in the previous phase of the research. By the authors.

workers, managers, politicians, etc. Through this type of expression, as well as representing the morphology of the routes, the aforementioned time sequence has been graphed, this being one of the determining factors for disabled people. In this article, as we shall see, we have chosen to delve deeper into this holistic understanding, which facilitates the approach to all the agents involved, although increasing the scale of work and the definition of the representations.

2. CASE OF STUDY

The case study we will use in this research is the Hospital Universitario Príncipe de Asturias (HUPA), located in the city of Alcalá de Henares (Madrid, Spain). It is a large referral health centre that, in addition to the inhabitants of this city, serves the residents of a significant number of smaller towns that are located around it. In total, the hospital serves some 252,180 inhabitants, approximately 78% of whom live in Alcalá. The location of the hospital on the outskirts of the town and disconnected from the urban fabric means that public transport is a fundamental element for the mobility of citizens due to its remoteness from the residential areas and neighbouring towns it serves. For this reason, this health complex is an ideal place to study the surroundings of the centre, where the different means of public transport converge, and, specifically, to analyse its degree of adaptation to current requirements in relation to the most vulnerable people.

3. BACKGROUND

The methodology of analysis of urban and architectural spaces has been put into practice in previous research that refers to this practice with the term "Space syntax" (Hillier et al., 1983). This methodology has been applied to the study of urban spaces in order to detect existing problems (dimensional, visual, communicative, etc.) and to make proposals for improvement in the fabric of the city and in its formal configuration (Haq & Luo, 2012); carrying out two-dimensional work fundamentally applied to the ground plan. On the other hand, other works have focused on the analysis of the times applied to the means of transport, calling this process "Time-motion" (Chías & Abad, 2017). Through this, it is possible to evaluate the incidence of this problem in the

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city's communications network, i.e. the ratio of time spent with respect to the space travelled, and to apply solutions for improvement. Finally, and as another methodology applied to the analysis of spaces from different perspectives, it is worth mentioning the "wayfinding" concept applied in previous research (Arthur & Passini, 1992; NHS England, 2005), which aims to study the route taken by users in the surroundings of different buildings and environments, paying special attention to signage and the design of the elements that facilitate the path (García Moreno, 2012). In general, the studies have been applied in a partial manner, which has made it impossible to obtain a general understanding of the space analysed; and, likewise, their methodologies have not used the new digital media available for recording reality and displaying the results in an accessible way. Therefore, although they constitute a valuable contribution to spatial analysis, they fall short of a multidimensional and holistic understanding of urban environments. In this sense, our contribution is particularly proactive, and goes far beyond the precedents, by dealing with the object of study in an integral way in all its variables, incorporating, as we shall see, the new means of digital 3D surveying for the analysis of these spaces and an intuitive and accessible graphic representation.

In this sense, there are numerous existing contributions on digital surveying using point cloud scanners, although they are mainly applied to the recording of cultural and architectural heritage (Manferdini & Russo, 2015; Remordino, 2011), and not so much to the analysis of spatial conditions and accessibility as in our case. In any way, we can point out the work for the survey of a complex outdoor space using point cloud laser scanning, where cavities abound in the ground plane (Parrinello, Bercigli & Bursich, 2017) or the registration of large-scale surfaces in the open field (Dong et al., 2022). We also highlight the work that, with different objectives, has also served as support for the research presented in this article. Specifically, for the survey of very complex buildings and the accuracy of the scanner with respect to other digital recording tools (Luhmann et al., 2019); for the understanding of historic buildings through the analysis and redrawing of the surfaces provided by the scanner (Onecha & Dotor, 2022); for the registration and documentation of infrastructures built with irregular materials (Trizio et al. 2001); or, for example, for the planning of the survey campaign (Gutiérrez-Pérez & De-Miguel-Sánchez, 2023).

Finally, it is essential to point out the importance of the work on the study of accessibility for people with disabilities in public spaces as a means of understanding the difficulties and architectural barriers they face, as well as the appropriate conditions for their proper development. These include technical documents and guides for the design of public space, both global (GDCI & NACTO, 2016), national (MTMAU, 2021 & 2022), regional (CAM, 2007) and local (Ayuntamiento de Madrid, 2016); as well as scientific works for the assessment of public space from the perspective of reduced mobility (Guevara-Quinchúa & France, 2023). In this sense, it is worth mentioning the work of Balado et al. (2018) that proposes a system for the classification of urban elements located at ground level (kerbs, steps, etc.) through automated software that uses laser scans as a basis; emphasising the importance that small-scale objects, such as pavements, acquire for mobility (Mackett, Achuthan, & Titheridge, 2008).

4. RESEARCH AIM

The main objective of this work is to unravel the possibilities that the inclusion of the 3D laser scanner can offer to the three-dimensional analysis of routes in complex buildings such as hospitals, paying special attention to barriers or facilitators in the environment in pursuit of universal accessibility.

Other objectives are to include vulnerable people, analyzing possible facilitators or barriers that may be encountered along this route; to elucidate new applications of the 3D laser scanner after this first contact and contrast with the analogue analysis; to search for an optimal treatment of the point clouds to highlight the important elements.

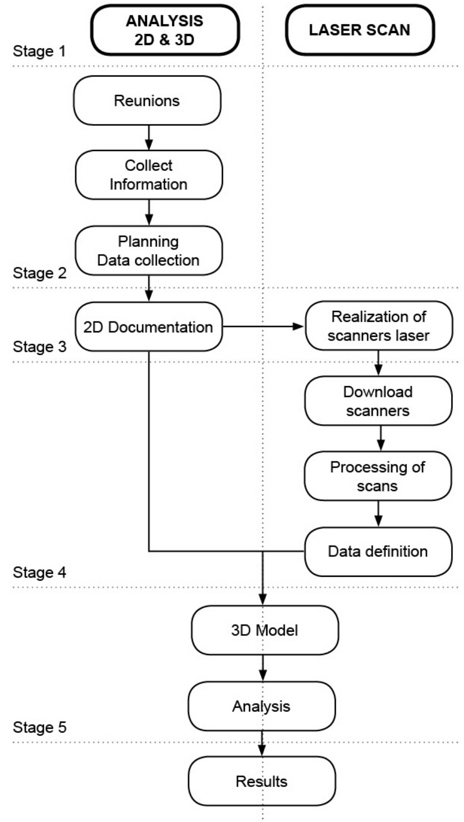

Fig. 2: Diagram of the applied methodology. By the authors.

5. METHODOLOGY

The methodology for this article begins with a first phase by bringing together the professional working team in initial meetings, in which the methodology to be followed is outlined. Information is also gathered, as well as planimetries and analyses carried out on the hospital's routes, data and analyses in previous studies.

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In addition, professionals are consulted about the different accuracies offered by the equipment according to the distance radius to determine the appropriate diameter and the distance between each scanner to be carried out. The 3D laser scanning equipment we have available to carry out the research is as follows: Leica RTC360 (2,000,000pts/s. and 1mm/10m accuracy) and Leica BLK360 (360,000pts/s. and 4mm/10m accuracy).
On-site data collection is planned and prepared with the available 2D planimetry, pointing out the points where the scans are to be taken. Up to now, the planimetry used and prepared has been generated with programs such as AutoCAD and Rhinoceros.
In the second phase of the study, once the data collection has been planned, it is carried out with the Leica BLK360 laser scanner. The scanner is programmed to take point clouds and panoramic photographs at each point. In this way, all the data provided by the laser scanner is collected, which is what this article is working on.
In the third phase, after obtaining the point cloud and panoramic photographs, the processing and analysis of this data begins using the Leica BKL Data Manager and Leica Cyclone REGISTER 360 programs. In these two programs, an initial cleaning and analysis of the point cloud is carried out. During this process, special attention is paid to universal accessibility and the facilitators and barriers that may affect vulnerable people along the route.
In the fourth phase, this data is transferred to Rhinoceros, passing through the CloudCompare software. In these programs, the data that the laser scanner contributes to the analysis are extracted and processed graphically using programs such as Adobe Photoshop and Adobe Illustrator. Finally, the results will be presented, combining previous analyses with the new analysis carried out with the 3D laser scanner, highlighting the information provided by the laser scanner, as opposed to the analyses obtained without this tool.
The analyses address the functional diversity of vulnerable users, considering in particular motor impairment and visual impairment. To this end, the physical elements that affect the quality of the path taken by these users and that can be studied digitally from the 3D scans are determined (Fig. 3). The strategy for classifying these elements into four major groups (accessibility, conservation, security and urban planning) is based on other reference analyses of pedestrian mobility (Guevara-Quinchúa & France, 2023) (Mackett et al., 2008), and also establishes the relationship of the particular physical elements with motor impairment and visual impairment.
Regarding the assessment that can be made of the quality of these physical elements, it should be noted that there are numerous technical regulations, both national and regional, on accessibility for people with motor disabilities. However, when consulting the above mentioned reference guides, it can be seen that there are many issues that the regulations either do not cover or cover without focusing enough on the ergonomics of public spaces, such as the ideal width of pavements. Therefore, these guidelines will also be taken into account in the assessment of the different elements analysed.
Regarding the valuation of the adequacy of the elements studied for the visually impaired, there are technical guidelines that establish the characteristics of the tactile footpaths. However, beyond guidelines and recommendations, there are still no regulations that are sensitive to other issues that also affect users with this disability, such as the sufficiency of artificial lighting or the morphology and graphics of signage. These elements must also be analysed from the perspective of visual impairment, since, according to the WHO, vision problems are very varied: mild vision impairment, moderate vision impairment -formerly called "low vision"-, severe vision impairment, blindness and near vision impairment (World Health Organization, 2019). This range of visual impairments indicates that these users may not only need foot-tactile signage, but, depending on their visual acuity ("a measure of the visual system's ability to discriminate two high contrast points in space"), may rely on other physical elements to help them orient themselves in urban space.

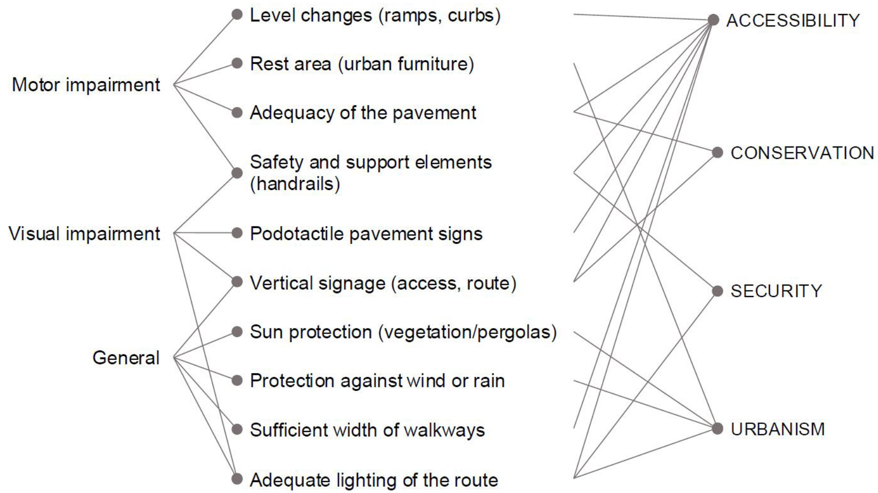

Fig. 3: Classification of the physical elements to be analysed. By the authors.

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6. WORK WITH POINT CLOUD DATA

Before starting with the on-site scans with the BKL360, a preliminary planning is carried out, marking the points at which each scanning point is to be done. Once the scans have been made, this information is transferred by means of the Data Manager to the computer with which you will be working. Once all the data has been transferred from the BKL360, the processing of the point cloud begins, as can be seen in Fig. 4. With the Cyclone Register 360, the different scans are linked and a small cleaning of the point cloud is started in order to be able to work with it in Cloud Compare, the program where the data necessary for the analysis is extracted. Finally, the results of the analysis are polished and displayed in AutoCAD.

6.1. WORKING POINT CLOUD GENERATION AND PROCESSING

To obtain the scans, the location from where each laser scanner is going to be carried out is previously considered. These points have been determined based on the precision data of the BLK360, knowing that in a circumference of 20 meters the precision is 8mm.
As can be seen in Fig. 5, there are 7 points from which to carry out each scan, always superimposing the circumference of 20 meters in diameter so as not to lose the precision of the point cloud on the path to be analyzed. However, when taking data in situ, it was decided to carry out two more scans: "05 bis", due to a building that interrupted the link between points 05 and 06, and "06 bis", since in situ there were obstacles that we wanted to scan from different angles. This leaves a total of 9 points to be scanned.
Once the scans had been carried out at each point, the data obtained was downloaded using the Leica Data Manager program, downloading both the point clouds and the panoramic photographs of each location.
The files obtained by the Leica Data Manager program are imported into the next program, Cyclone REGISTER 360, where the first processing of the point cloud is carried out. The steps followed to process the point cloud are as follows: first, the scanning points are linked together, both in plan and in elevation, until all the scanning points are linked together; second, a copy version is created before deleting points and captures are taken of the work in the current state; thirdly, only the area to be studied is extracted, in this case, the route to be taken by the users, eliminating the rest of the environment, with the intention of making the objects that interrupt the path more visible; fourthly, the clouds of points that correspond to users who took the route during each scan are eliminated; finally, captures are taken and the data are exported to be processed with the next program.

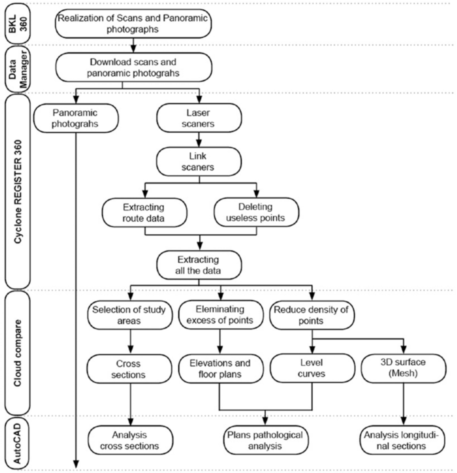

Fig. 4: Summary of working methodology. By the authors.

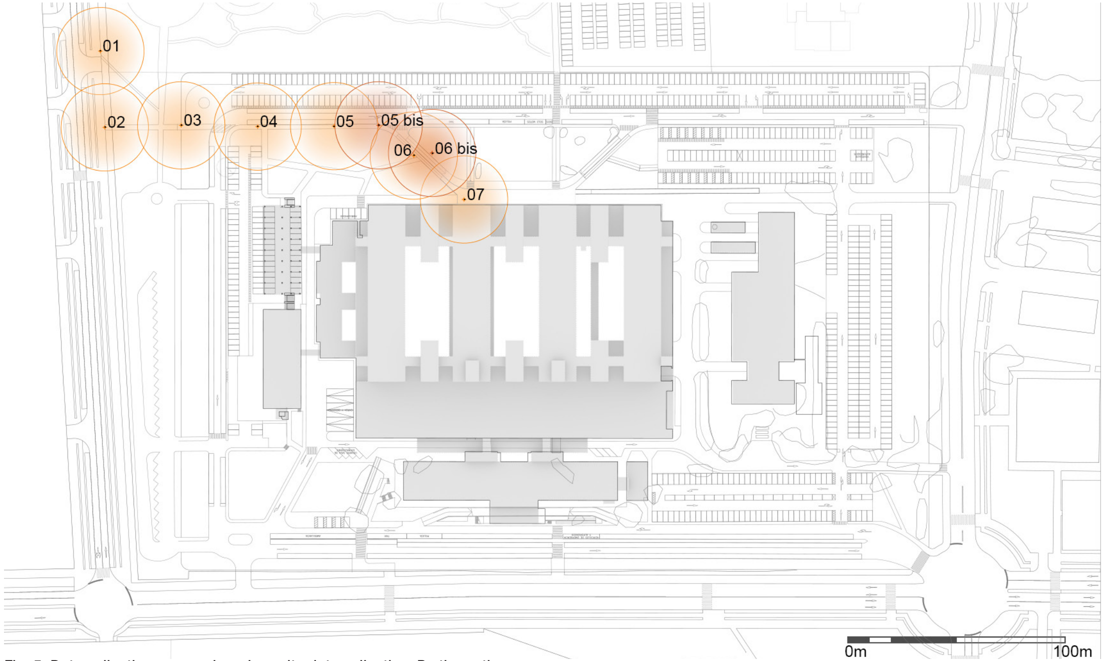

Fig. 5: Data collection approach and on-site data collection. By the authors.

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After the work carried out on the file using Cyclone REGISTER 360, having made the cut-out in plan, all the objects that invade the traffic space are easily located. We can see in Fig. 6 how we can detect at a glance obstacles such as A, a vehicle that invades the pavement, B, a sign that is located on the road, C, urban furniture that occupies part of the route, D, bollards that have been placed on the pavement...
This same figure also shows the type of pavement such as: the tactile footpath, the pavement tiles and the perimeter finish. In addition, other elements like trees and urban furniture that cast shade or light are also located, making it possible to study them.

6.2. EXTRACTING DATA FROM THE POINT CLOUD

The planning of the digital work to be carried out starts with the prior classification of all the elements that affect the aforementioned vulnerable users, and the ana lyses are divided into three main areas: accessibility analysis of slopes and ramps, detailed analysis of pavements and analysis of urban elements (Fig. 8). In each of these, specific questions will be posed to assess the quality of the route, finally determining which graphic information provides the most information to answer these questions.
To obtain this information, the workflow is planned with different programs: point cloud processing and surface generation programs (Leica, Cloud Compare), CAD programs (AutoCAD, Rhinoceros) and image processing programs (Photoshop, Illustrator).

6.2.1. ACCESSIBILITY ANALYSIS OF SLOPES, RAMPS AND PAVEMENTS

To obtain the topographic information, the original point cloud is preprocessed. This initially consists of almost 115 million points, which requires a large RAM memory and processor capacity of the equipment used. Given that micro-level data are not required at this stage, it was decided to reduce the number of points to 10% with the Cloud Sub Sampling tool, obtaining a more manageable dataset suitable for the scale of work. The contour lines every 10 cm and a surface (mesh) are generated with the Rasterize tool, exporting the contour lines to DXF format and the surface to PLY format. The surface is then imported into Rhinoceros (CAD) where the longitudinal section of the route is made and the dihedral views are obtained. This two-dimensional information is exported again to DXF to finally work in the AutoCAD environment.
Fig. 9 shows an analysis of the types of pavements along the route travelled by the user from the bus stop to the main entrance of HUPA. As can be seen, when getting off the bus, the user has to cross a lane dedicated to bicycle traffic. Once you have crossed the cycle lane you reach the area paved with concrete cobblestones, however, continuing the route, to reach the limits of the hospital plot you must cross a dirt road. It is from the limits of the hospital plot that the footpath begins in the center of the road, with concrete cobblestones on either side. These two textures continue until the entrance to HUPA, interrupted by a lane for motorized vehicles. All the pavements could be observed and analyzed in the point cloud generated by the laser scanner.

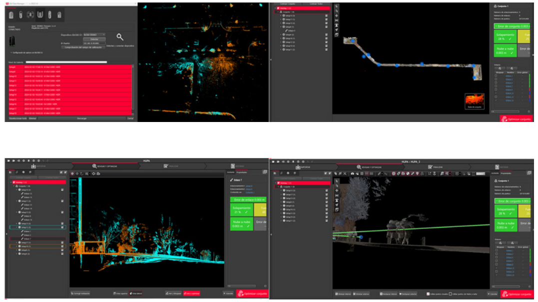

Fig. 6: Steps inside Cyclone REGISTER 360. By the authors.

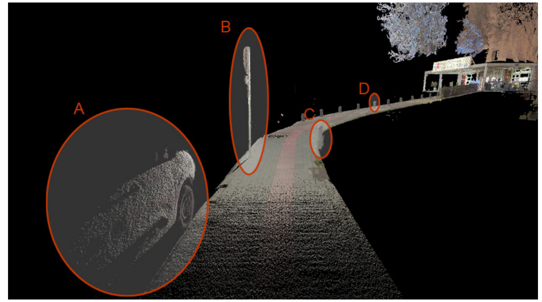

Fig. 7: Perspective inside cloud of points. Program Cyclone REGISTER 360. By the authors.

Analysis	ACCESSIBILITY	SECURITY	CONSERVATION	URBANISM	Questions addressed	Information type	Digital elements	Software: Leica	Software: Cloud Compare	Software: CAD	Software: Image
• Accessibility of slopes and ramps	X			X	• Compliance with technical standards	• Topographic	• Contour lines	X	X		
							• Longitudinal section of the itinerary	X	X	X	
• Detailed pavement analysis	X	X	X		• State of conservation • Typology • Adequacy	• Photographic and vectorial	• Panoramic photographs	X			X
							• RGB point cloud plan	X	X		
							• Pathological analysis plan	X	X	X	
• Analysis of urban elements: furniture, vegetation and signage.	X		X	X	• State of conservation • Number and type of elements: artificial lighting, signage, rest areas, etc.	• Photographic, vectorial two- and three-dimensional	• Panoramic photographs	X			
							• Elevations / point cloud plans	X	X		X
							• Cross sections	X	X	X	
					• Shading and protection elements	• Two-dimensional vector, photographic	• Point cloud elevations	X	X		
							• 2D elevations and floor plans	X	X	X	

Fig. 8: Digital analysis planning table: elements analysed, questions posed, digital elements to be obtained and software to obtain them. By the authors.

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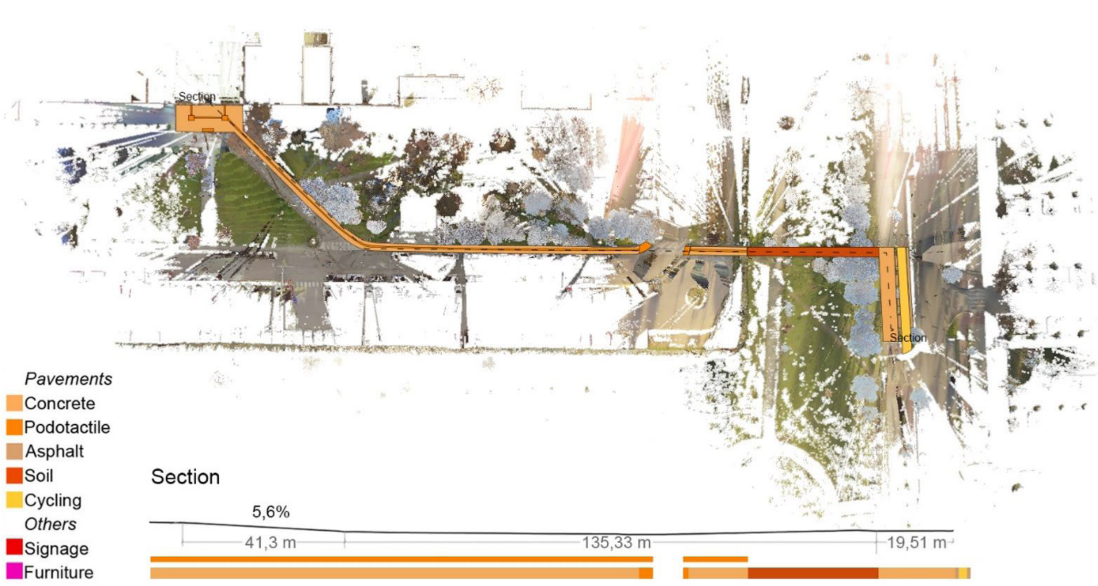

Fig. 9: Types of pavements. By the authors.

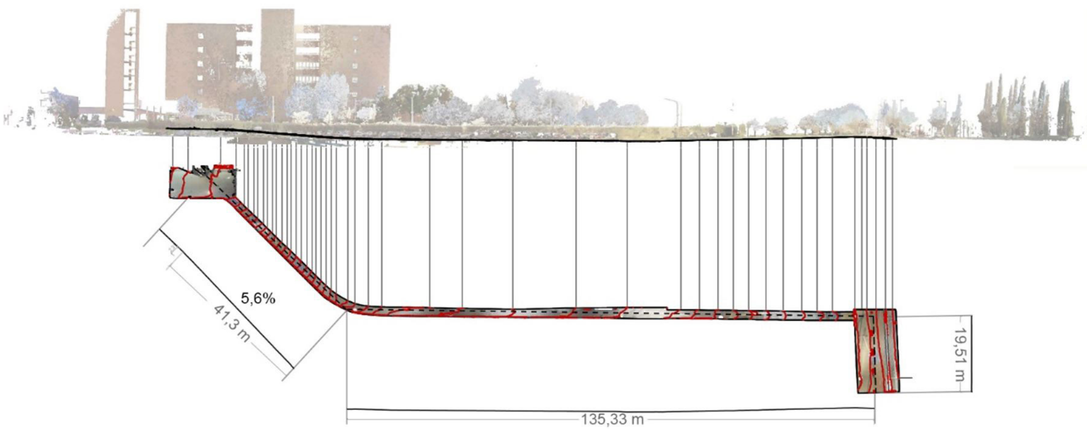

Fig. 10: Analysis of topography. By the authors.

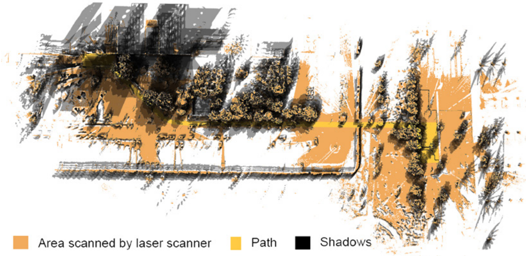

Fig. 11: Sunstroke during 21 June between 10 am and 17 pm. By the authors.

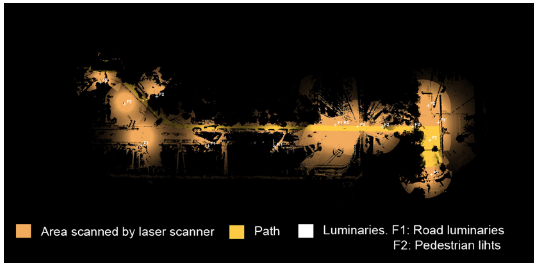

Fig. 12: Plant of luminaries. By the authors.

Fig. 10 shows the study and analysis of the topography, highlighting the slope of the ramp that precedes the plain corresponding to the hospital entrance. This slope has a percentage greater than 5% and is 41.3 m long. To comply with the regulations in force in the Community of Madrid (CAM, 2007), the ramp should have a maximum length of 9 m to classify the route as accessible.

6.2.2. ANALYSIS OF URBAN ELEMENTS: VEGETATION AND LIGHTING

The sunlight study was carried out on the sunniest day in Spain, 21 June, to observe the change in the direction of the shadow cast on the path to be analysed. Fig. 11 shows that the user experiences changes in lighting along the route, which can be detrimental to people with sight pathologies. It can also be seen how most of the route is protected from the sun from the central hours until sunset, providing comfort throughout the seasons of the year when the sun punishes users.

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Fig. 13: Comparison of rendered elevations from Cloud Compare. Original elevation (top) and elevation scaling the RGB points (bottom). By the authors.

Fig. 14: Location of the detailed study areas. Top view (point cloud). By the authors.

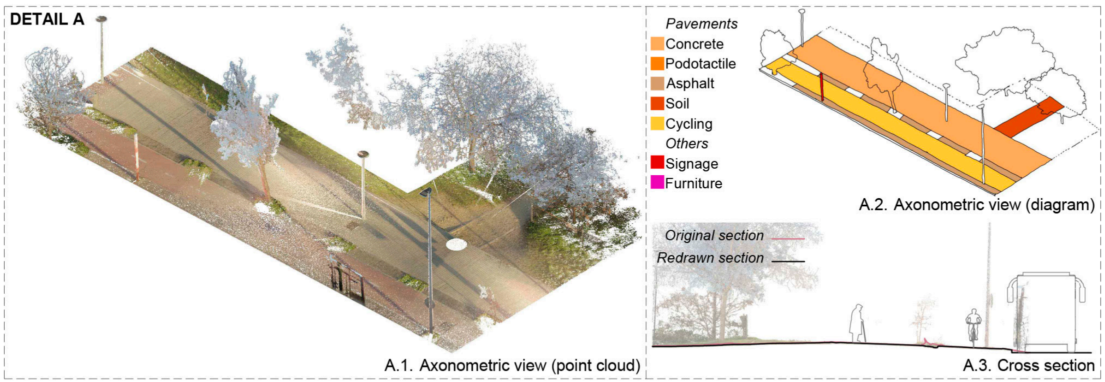

Fig. 15: Detailed analysis of point A. By the authors.

In the lighting study during the evening and night the path is mostly illuminated, although in the central area of the route it seems to lack sufficient illumination, as is also the case at the beginning of the ramp. Among these luminaires there are road luminaires, dedicated to the illumination of the car roads, and the pedestrian luminaires, dedicated to the route provided for users coming to the hospital on foot.

6.2.3. ANALYSIS OF URBAN ELEMENTS: IN-DEPTH STUDY OF FURNITURE, PAVEMENTS AND SIGNAGE

Micro-level data is analysed at representative points along the route studied, in order to identify elements related to accessibility, safety and urban design from a smaller scale, possible by means of the hyper-real image provided by the 3D scanner. For this purpose, high-quality samples are taken from the general point cloud (Fig. 14) and processed with different tools. First, with CloudCompare, dihedral and axonometric views of each studied area are rendered, and then cross-sectional and longitudinal sections are generated and exported to DXF format. These are transferred to a CAD program, where inaccurate or erroneous parts are redrawn by hand. Freehand diagrams of the axonometric views are made in an image editing software (Photoshop), highlighting those elements of greatest interest for the research (pavements, street furniture, vegetation, railings and handrails, vertical signage, etc.).
The results show different problems in each of the areas. At the starting point of the route (Fig. 15), given that this is the point of arrival at the hospital by bus, the stop does not have a bus shelter, with only a signpost marking this point. Disembarking from the bus takes place on a narrow asphalted strip on the pavement, and immediately afterwards the patient arriving at the hospital must cross a two-way cycle lane (Fig. 15, section A.3), which poses a safety risk due to the possible collision between users of this lane and the pedestrian getting off the bus. The bus stop is a few metres away from the start of the road to the hospital (Fig.

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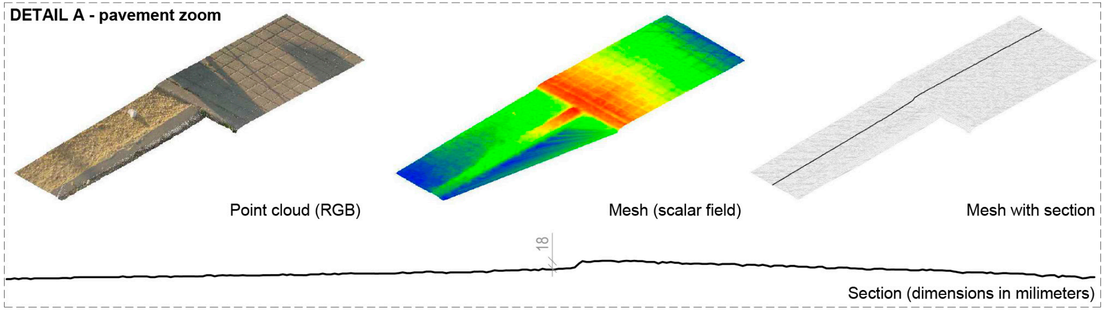

Fig. 16: Detailed study of the kerb separating the paved area from the unpaved path. By the authors.

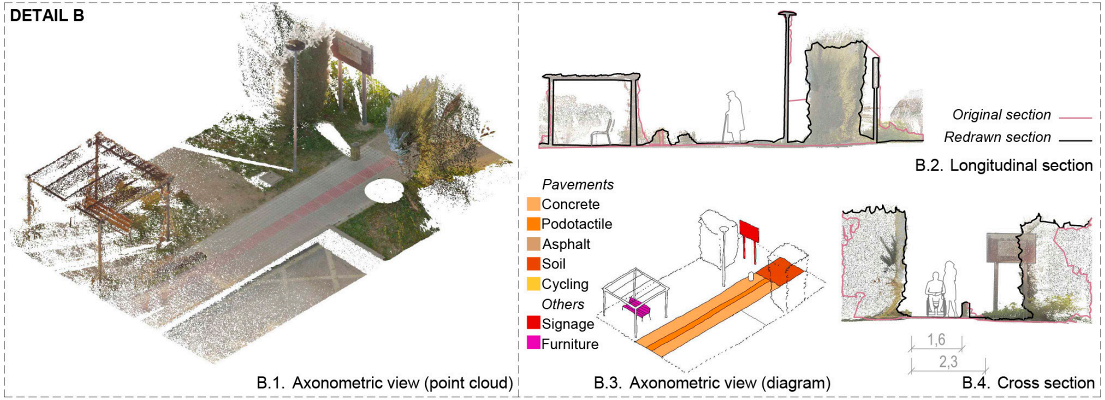

Fig. 17: Detailed analysis of point B. By the authors.

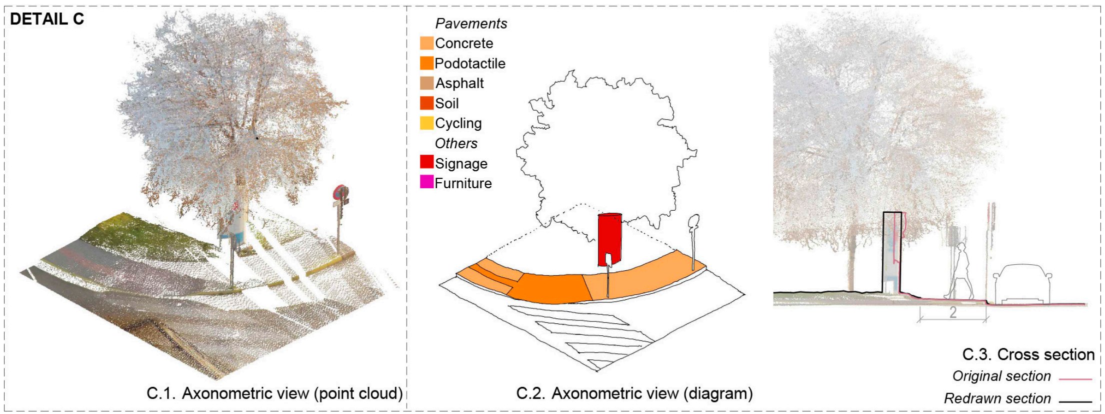

Fig. 18: Detailed analysis of point C. By the authors.

15, diagram A.2), and there are no visible signs to highlight it. To reach it, it's necessary to cross four areas of different pavements separated by concrete kerbs that are not at ground level.
The last kerb, which separates the paved path from the unpaved path, deserves a special mention. Using the micro-level data available with the 3D scanning, the gap between the two areas is measured (Fig. 16). For this, a fragment of the point cloud is taken in high quality from CloudCompare, extracting the surface of these points (mesh). This is then worked in a CAD program to obtain the longitudinal section. As shown in the section, the projection is 18 mm, which makes it difficult for people in wheelchairs as it exceeds the 4 mm specified in the current regulations (MTMAU, 2021). Furthermore, according to these regulations, the unpaved path does not meet the necessary conditions for an accessible route, as it is not "hard and stable".
The unpaved path ends at the edge of the hospital plot (Fig. 17) and becomes a paved path with a tactile footpath. The first vertical sign indicating that the patient is on the HUPA site is located at the start of the path. There is also a low bollard that reduces the width of the walkway (Fig. 17 section B.4) to a dimension below that recommended in international accessibility guidelines - 2 metres according to the GDCI & NACTO (2016) - and not admissible in the regional guidelines for accessible routes, which restrict it to 180 cm (Ayuntamiento de Madrid, 2016). In addition, this bollard can be tripped over by visually impaired people.
This section contains the only piece of urban seating furniture along the entire route: a bench on the side of the path, carefully protected by a pergola. This rest area does not have a paved floor, which would be desirable to make it more accessible from the main path.
At the intersection with the road inside the hospital grounds (Fig. 18) there is another vertical sign, giving continuity to the signage seen in the previous section. Although there are other vertical traffic signs that may make it difficult to see the whole of this one, it is large enough to be visible. The tactile footpath crossing is correctly

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signposted, although it is true that the crossing at the end of the curve may make it difficult to see vehicles on both sides of the road.

The straight path from the junction to the proximity of the hospital entrance (Fig. 19) is sufficiently wide, according to the references previously studied (GDCI & NACTO, 2016). However, on one of the sides, parking spaces are located in line, so that the landing of people will necessarily invade the width of the pavement (Fig. 19 floor D.2). On the other side, a large wooded area provides shade for pedestrians.

In the final section of the route (Fig. 20), the patient faces a large ramp (41 metres long, as seen in the previous analyses) whose gradient exceeds 4%. According to current technical regulations (MTMAU, 2022), accessible ramp sections should not exceed a length of 9 metres (Fig. 20 section E.2), and should have intermediate rest areas to ensure that users do not fatigue. On the other hand, the existence of side protections against vehicular traffic (bollards) again reduces the useful width of the pavement to a dimension that makes it difficult for users with reduced mobility to pass simultaneously (Fig. 20 section E.4). The last vertical signage of the hospital is located in this section, although its orientation parallel to the road suggests that it is intended, not for users of this route, but for those coming from a lateral path (Fig. 20 diagram E.3).

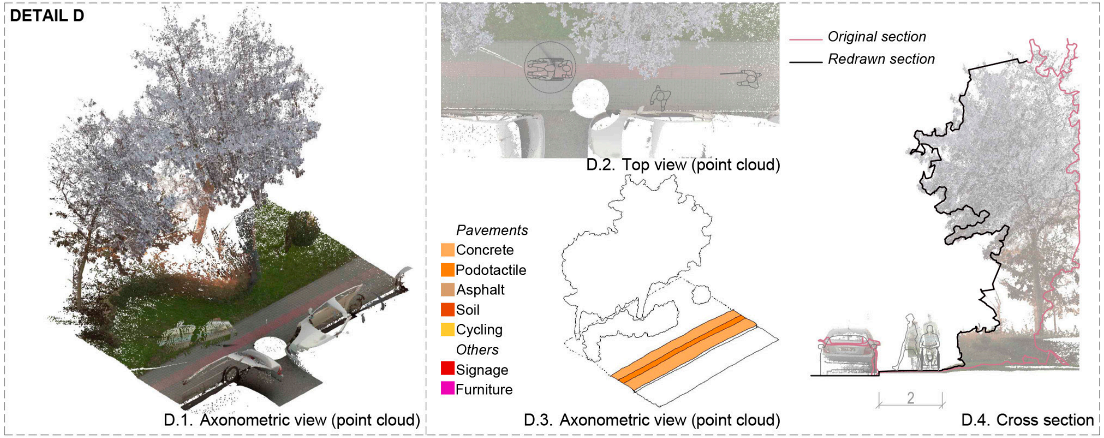

Fig. 19: Detailed analysis of point D. By the authors.

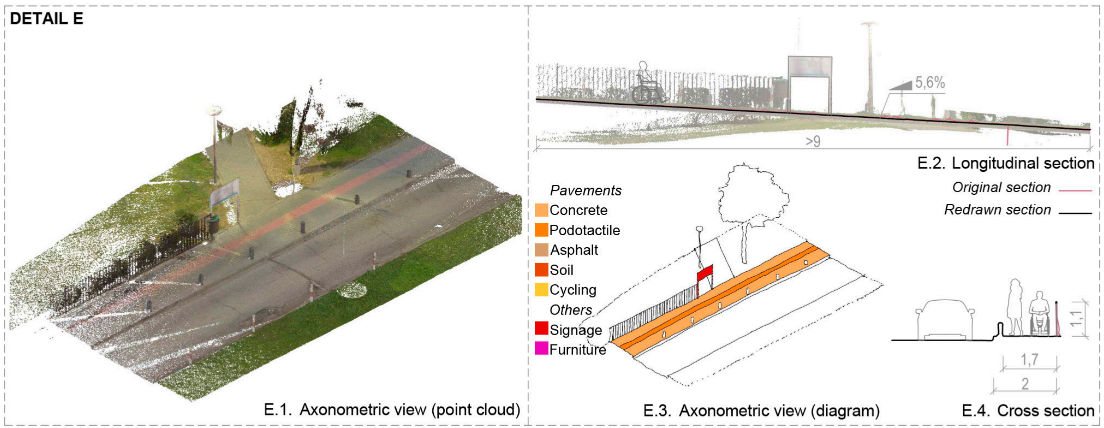

Fig. 20: Detailed analysis of point E. By the authors.

7. CONCLUSIONS

This work represents a methodological advance in the study and analysis of accessibility in hospital environments as a means of identifying accessibility problems and assessing the degree of integration of vulnerable people. This work has given continuity to our own research, which was based on a previous analysis to identify the most stressed routes and which has allowed us to determine the location of the work areas for this second phase. Therefore, there has been a scalar and detailed approach that accurately defines the qualities of the architecture, urbanisation and landscape of the spaces analysed as a fundamental step for the identification of their physical conditions: types of pavements, urban furnishings, lighting, vegetation, etc. In this task, the point cloud laser scanner was used as a support for the survey of the routes analysed, recording with great precision all the elements of the environment and, in short, facilitating a holistic interaction with the object of study. After the manual work of discrimination of the data obtained by scanning, and the subsequent work with different applied software, it has been possible to analyse in depth

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and expose the problems found along the route in an effective manner, thus fulfilling the initially proposed objectives. With all this, the application methodology proposed and developed in this research is intended to serve for the analysis of other case studies and, therefore, as a support for the implementation of proposals for improvement and reform in hospital environments, as well as in other complex urban spaces.

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REFERENCES

Balado, J., Díaz-Vilariño, L., Arias, P. & González-Jorge, H. (2018) Automatic classification of urban ground elements from mobile laser scanning data. *Automation in Construction*, 86, 226-239. doi: 10.1016/j.autcon.2017.09.004

Chías, P. & Abad, T. (2017). Green hospitals, green healthcare. *International Journal of Energy Production and Management*, 2 (2), 196-205.

CAM - Comunidad de Madrid (2007). Reglamento Técnico de Desarrollo en materia de promoción de la accesibilidad y supresión de barreras arquitectónicas.

Domínguez, P., Gutiérrez, N., Cambra, L., Sánchez-Jáuregui, T., de Miguel, M. & Chías, P. (2023) Modelo gráfico multidimensional para el análisis de flujos y circulaciones en hospitales: Caso de estudio: el Hospital Universitario Príncipe de Asturias. *EGA Expresión Gráfica Arquitectónica*, 28(49), 208–223. doi: 10.4995/ega.2023.19575.

Dong, Z., Liang, F., Yang, B., Xu, Y., Zang, Y., Li, J., Wang, Y., Dai, W., Hongchao, F., Hyyppa, J. & Stilla, U. (2020), *ISPRS Journal of Photogrammetry and Remote Sensing*, 163, 327-342. doi: 10.1016/j.isprsjprs.2020.03.013

García Moreno, D. (2012). Diseño de Sistemas de Orientación Espacial: Wayfinding. In *Accesibilidad universal y diseño para todos* (2011), 36-57, Madrid: ONCE, Fundación Arquitectura COAM.

GDCI & NACTO - *Global Designing Cities Initiative & National Association of City Transportation Officials* (2016). Global street design guide.

Guevara-Quinchúa, Y. & France, A. (2023). Evaluación del espacio público para personas con movilidad reducida. *Cidades* [Online], 46. doi: 10.15847/cct.27635

Gutiérrez-Pérez, N. (2023) Cultural heritage recovery in rural Spain through digital means of surveying and graphic reconstruction. Case study of El Paular wool complex. *SCIRES-IT*, 13(1), 67-82. doi: 10.2423/i22394303v13n1p67

Gutiérrez-Pérez, N. & De-Miguel-Sánchez, M. (2023) A scalar approximation to the survey of the architectural, artistic and cultural heritage of the University of Alcalá (Madrid, Spain). *DISEGNARECON*, 16 (30), DW1-DW13. doi: 10.20365/disegnarecon.30.2023.5

Gutiérrez Pérez, N., Domínguez Gómez, P., Sánchez-Jáuregui Descalzo, T., Chías Navarro, P. (2024). The Integration of People with Disabilities into Hospital Surroundings: A Drawing Based Approach. In: Hermida González, L., Xavier, J.P., Sousa, J.P., López-Chao, V. (eds.) *Graphic Horizons. EGA 2024. Springer Series in Design and Innovation , vol 42.* Springer, Cham. doi: 10.1007/978-3-031-57583-9_25

Haq, S. & Luo, Y. (2012). Space Syntax in healthcare facilities research: A review. *Health Environments Research and Design Journal*, 5 (4), 98-117.

Hillier B., Hanson J., Peponis J., Hudson J. & Burdett R. (1983). Space syntax, a different urban perspective. *Architects' Journal*, 178, 47-63.

Luhmann, T., Chizhova, M., Gorkovchuk, D., Hastedt, H., Chachava, N., & Lekveishvili, N. (2019) Combination of terrestrial laser scanning, UAV and close-range photogrammetry for 3D reconstruction of complex churches in *Georgia. Int. Arch. Photogramm. Remote Sens. Spatial Inf. Sci.*, XLII-2/W11, 753-761. doi: 10.5194/isprs-archives-XLII-2-W11-753-2019

Mackett, R., Achuthan, K. & Titheridge, H. (2008) Making streets more accessible for people with mobility difficulties. *Urban Des Int*, 13, 81–89. doi: 10.1057/udi.2008.12

Manferdini, A.M., & Russo M. (2015) Dal rilievo alle rappresentazioni ad alta risoluzione dello spazio architettonico continuo. Il caso di studio del complesso dell'Abbazia di Pomposa. *DISEGNARECON*, 8 (14), 1.1-1.12.

MTMAU - Ministerio de transportes, movilidad y agenda urbana (2021). *Guía de accesibilidad en los espacios públicos urbanizados* V.1.0.

MTMAU - Ministerio de transportes, movilidad y agenda urbana (2022). *Código Técnico de la Edificación, Documento Básico de Seguridad de Utilización y Accesibilidad.*

NHS England, (2005). *Wayfinding: effective wayfinding and signing systems guidance for healthcare facilities.* DH Department of Health.

Parrinello, S., Bercigli, M. & Bursich, D. (2017) From survey to 3d model and from 3d model to "videogame". The virtual reconstruction of a Roman Camp in Masada, Israel. *DISEGNARECON*, 10 (19), 11.1-11.19.

Onecha, B. & Dotor, A. (2022) Method for improving structural comprehension of historical buildings based on terrestrial laser scanner technology. *EGA Expresión Gráfica Arquitectónica*, 27(46), 100–109. doi: 10.4995/ega.2022.17379

Remondino, F. (2011) Heritage recording and 3D modeling with photogrammetry and 3D scanning. *Remote Sensing*, 3(6), 1104–1138. doi: 10.3390/ rs3061104.

Trizio, I., Marra, A., Savini, F., & Fabbrocino, G. (2001). Survey methodologies and 3d modelling for conservation of historical masonry bridges. *ISPRS Ann. Photogramm. Remote Sens. Spatial Inf. Sci.*, VIII-M-1-2021, 163-170. doi: 10.5194/isprs-annals-VIII-M-1-2021-163-2021

United Nations (2006). *Convention on the Rights of Persons with Disabilities*. United Nations: New York, NY, USA, 2006.

World Health Organization (2019). *World report on vision*. Geneva: World Health Organization.

DOI: https://doi.org/10.20365/disegnarecon.32.2024.2