RIVISTA ITALIANA DI ERGONOMIA
ORGANO UFFICIALE DELLA S.I.E. - SOCIETÀ ITALIANA DI ERGONOMIA E FATTORI UMANI

INTEGRATING CONFIGURATIONAL ANALYSIS AND AGENT-BASED MODELING FOR INCLUSIVE WAYFINDING: AN ERGONOMIC FRAMEWORK FOR MUSEUM ENVIRONMENTS

Gianmauro Romagna [1], **Teresa Villani** [2]

[1] CNR ISTC- National Research Council, Institute of Cognitive Sciences and Technologies, Rome, Italy
[2] Department of Planning, Design, and Technology of Architecture, Sapienza University of Rome

KEYWORDS: *Agent-based Modeling, Museums, Predictive usability, Space Syntax, Universal Design, Wayfinding*

ABSTRACT

Designing a museum visitor experience is a complex challenge that involves both exhibition aspects and the cognitive processes involved in reading/interpreting the space and understanding pathways. From an ergonomic perspective that focuses on the interaction between the museum environment and visitors, it is important to consider wayfinding in an adaptive and inclusive way to ensure expanded usability, especially for users with special needs. The potential offered by the digitization of heritage today allows the use of models capable of simulating scenarios of use in relation to the spatial configuration, the exhibited content, and visitor behavior. Studies conducted on the Space Syntax methodology show how spatial configuration influences the perception and interpretation of routes and artworks. At the same time, Agent-Based Models simulate the behavior of different users in virtual environments that match real-world conditions, providing information on disorientation, crowding, and accessibility. Although these models are available, they are often applied separately, preventing a unified view of usage dynamics. Their operational convergence would allow for a deeper understanding of how space is used, considering that people's movement structures space and, conversely, influences behavior and exhibition choices. This paper therefore explores this integration to support flow assessment and guide design decisions. The case study of the "Amedeo Maiuri" archaeological museum in Veroli made it possible to test predictive models on a controllable scale. Preliminary results highlight critical issues in spatial interpretation and suggest design directions to improve its intelligibility. Future integration into BIM-based tools could enable coordinated management of inclusive wayfinding systems.

COGNITIVE AND PERCEPTUAL ERGONOMICS FOR WAYFINDING IN MUSEUMS

In complex contexts, such as museums, space is not simply a container of functions, but an active component of the cultural experience. Every defining element, from morphology to dimensions, from material characterization to lighting, contributes to guiding the exhibition narrative. Therefore, the space's ability to be read and interpreted by visitors becomes an integral part of the experience itself, guiding their perception and movements.nConsidering how

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these dynamics shape experience, cognitive and perceptual ergonomics, which studies the mental processes connected to environmental perception, including attention, memory, and orientation (Francis & Amadi, 2015), provides a valuable theoretical lens for understanding how space shapes interpretive processes. This is even more relevant when considering the museum environment as a device capable of activating relationships between visitors (Di Benedetto, 2021). As a result, design quality must account for the social, cognitive, and emotional factors that influence the visiting (Zammuner, 2006). From this perspective, environmental intelligibility (Lynch, 1960), or the ability of built space to offer a clear and recognizable structure, becomes fundamental for the formation of coherent mental maps and for orientation. Its enhancements become tools for wayfinding, understood not as a simple study of signage, but as a cognitive process shaped by spatial configuration (Arthur & Passini, 1992; Farr et al., 2012). Wayfinding is also recognized as a core element of universal accessibility, and measures to address and manage it are an integral part of the PEBA (Strategic Plan for the Elimination of Architectural Barriers in Museums, Libraries, and Archives) (MiC, 2018). Recommendations for facilitating intelligibility, interpretation, and independent navigation of spaces fall squarely within the principles of Universal Design (Mace, 1997; Clarkson et al. 2013). Given this close relationship, the design of cultural sites should take route management and orientation as guiding criteria, understood as a dynamic relationship between people's movement and the perception of spaces, always interconnected with the cultural dimension and the construction of an equitable experience of heritage (Lisney et al., 2013). The study of these aspects is now facilitated by the digital transition, which enables knowledge and predictive management of the built environment (Daniotti et al., 2020; Casini, 2021) and opens new perspectives for building integrated information models capable of interpreting, simulating, and optimizing the visitor experience (Andersen et al., 2021; Ferretti et al., 2022) and the management of spaces and content (Centorrino et al., 2021; Ceccarelli et al. 2024; Villani et al. 2024). In this context, the paper explores the contribution of digital technologies to the ergonomics approach applied to analyzing the spatial intelligibility of cultural sites. It highlights how simulation models that study movement based on spatial and behavioral factors can incorporate Universal Design principles, ensuring human-centered design that supports accessible and inclusive cultural experiences. It proposes an integrated predictive framework that, by combining simulations based on both spatial syntax and behavioral agent modeling, allows for the inclusive assessment and improvement of the intelligibility and usability of museum spaces, supporting design decisions for wayfinding. The originality of the proposed framework, validated through a case study, lies in the systematic integration of two simulation fields previously treated and applied separately, allowing for the correlation of spatial structure, cognitive orientation processes, and behavioral dynamics within a unified predictive framework for evidence-based and inclusive design.

PREDICTIVE MODELS FOR THE EVALUATION OF SPATIAL INTELLIGIBILITY AND THE STUDY OF MOVEMENTS: SPACE SYNTAX AND AGENT-BASED MODELING

The use of digital tools to simulate the interaction between users and built spaces constitutes a strategic research area for inclusive design and management of cultural sites. Understanding how spatial morphology impacts perception, behavior, and wayfinding processes has led to the development of predictive models capable of translating person-environment relationship into objective metrics supporting design decisions. Within this framework, two

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main interpretative approaches have emerged in the literature, each linked to a specific simulation paradigm. The first, which focuses on spatial layout and the role of geometric organization in the comprehensibility of environments, involves configurational analysis, based on the theory of Space Syntax (Hillier & Hanson, 1989; Hillier, 2007), which interprets space through graphs and quantitative metrics (visual integration, connectivity, etc.), assessing environmental intelligibility in relation to visual permeability. The results, in the form of color maps, enable the prediction of movement patterns and the identification of central or marginal areas, providing concrete support for design. Widely applied in museums (Hillier & Tzortzi, 2006), this technique has proven effective in predicting visitor flows and optimizing visitor routes. Rohloff (2009) analyzes the Yale Center for British Art (YCBA), the Museum of Modern Art (MoMA) in New York, and the High Museum of Art (HMA) in Atlanta by comparing spatial configurations and their influence on visitor routes, demonstrating how more integrated areas tend to receive greater attention, while peripheral or poorly connected spaces are rarely used, regardless of the quality of the works exhibited. Similarly, Dursun (2007) highlights that, in the proposed expansion of the Tate Britain in London, solutions that are most integrated with existing spaces are preferable; while at the British Museum, some central galleries act as attractor nodes, leaving less connected areas marginalized. Despite its analytical effectiveness, this approach is based on a homogeneous representation of human behavior, which is poorly suited to capturing the complexity of real-world cognitive strategies, especially when considering people with special needs, whose ways of orienting, perceiving, and interacting with the environment may deviate significantly from standardized models. The second interpretative axis, Agent-Based Modeling (ABM), fits precisely in this direction. It is a simulation paradigm oriented towards emergent behavior (Helbing, 2012) that is based on the modeling of virtual agents that interact with the environment and with each other, following customizable decision-making rules (Helbing & Grund, 2013). Unlike Unlike flow-based mathematical models (Hughes, 2003; Farooq et al., 2020), ABM represents individuals as distinct entities, profileable based on age, ability, familiarity with space, and interests, offering greater realism. Although still little used in the museum sector (Feng et al., 2020), it has found consolidated application in highly complex environments, such as stations (Liu & Chen, 2023), airports (Li & Wu, 2025), hospitals (Zambrano et al., 2016), and mass events (Mahmood et al., 2017), to simulate flows, prevent congestion, and test management strategies. The dynamic and highly customizable results include density maps, time and critical area analyses, and alternative scenario evaluations. However, technical complexity and computational demands require interdisciplinary collaboration, representing both a challenge and an opportunity for inclusive design processes. Given the limitations and potential of both tools, the need for an integrated approach emerges, combining the analytical robustness of configurational analyses to formalize spatial structure with the behavioral flexibility of ABM. Only a design vision capable of articulating both dimensions can support the creation of truly accessible, cognitively legible, and user-centered museum spaces. The integration of the two approaches enables the development of robust predictive models to support evidence-based design decisions, in line with cognitive ergonomics, the principles of Universal Design, and the digital transition applied to cultural experience.

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CASE STUDY: THE "AMEDEO MAIURI" ARCHAEOLOGICAL MUSEUM OF THE ITALIC PEOPLES IN VEROLI

The integration of these predictive models finds concrete application in the "Amedeo Maiuri" Museum, selected as a case study for its ability to represent, on a small scale, the challenges of digitally managing spatial intelligibility within an inclusive framework. The museum is housed in the eighteenth-century Palazzo Marchesi Campanari, in the historic center of Veroli (FR), spread over four floors, including a basement, connected by a central staircase. The building, characterized by vaulted rooms and a fine decorative apparatus, reflects its noble origins through significant architectural stratification. Established in 2023, the museum presents the history of the pre-Roman populations of southern Lazio, particularly the Hernici, Volsci, and Latini. Since its opening, it has hosted a series of exhibitions that have defined its curatorial profile, including Ancient Italic Peoples: the Ernici, the Volsci, and the Others (December 2023) and Poet of Archaeology. Amedeo Maiuri between Lazio and Campania (December 2024). The new exhibition, scheduled for inauguration in early 2026, encompasses three of the four levels and represents the outcome of a comprehensive renovation project co-financed under the PNRR – Mission 1, Investment 1.2: Removal of physical and cognitive barriers in museums, libraries, and archives. The renovated spatial and experiential itinerary includes the main entrance in the basement (Figure 1a), dedicated to service functions, including the ticket office, restrooms, deposit, and a conference room. A new elevator (under construction) provides access to the ground floor (Figure 1b), home to the permanent exhibition where the curatorial narrative spans the cultures, languages, and territories of the Italic peoples. In addition to the direct exit onto Via Umberto I, the floor also features two immersive rooms: one dedicated to the history of the building, through an interactive podcast, and one dedicated to the practice of transhumance, configured as a multisensory experience, designed with the participation of associations for people with disabilities in the province of Frosinone. Finally, the first floor (Fig. 1c), also served by an elevator, hosts temporary exhibitions, with a specialized focus on necropolis and on the work of archaeologist Amedeo Maiuri, to whom the main hall is dedicated. The project is part of a broader framework of initiatives aimed at promoting universal accessibility to this site and is the subject of a research agreement between the Department of Planning, Design, and Architectural Technology (PDTA) of the University of Rome "La Sapienza" and the Regional Directorate of National Museums (DRMN) of Lazio. This collaboration aims to test advanced solutions for wayfinding and multisensory accessibility, combining approaches from architectural technology and digital disciplines. From this perspective, the museum's characteristics (small scale, morphological complexity, historical value) make it an experimental laboratory for technological innovation and cultural inclusion, a benchmark for defining quality standards in the management and valorization of cultural heritage for all.

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Figure 1. The plans of the new exhibition of the Archaeological Museum of the Italic Peoples "Amedeo Maiuri" in Veroli: (a) the main entrance and public services in the basement, (b) the permanent exhibition and the immersive rooms on the ground floor (c) the temporary exhibition and the "Maiuri" room on the first floor.

TOWARDS AN ERGONOMIC FRAMEWORK FOR MUSEUM WAYFINDING: ARTICULATION OF THE METHODOLOGY

The methodological approach of this study stems from the need to integrate the contribution of cognitive ergonomics applied to museum wayfinding design with the potential of the mentioned predictive models and is structured into three distinct but complementary phases (Figure 2). In line with a human-centered approach (Attaianese & Duca, 2012), the first phase (Design Briefing) aims to clarify the needs of the wayfinding project by identifying factors influencing route intelligibility and the desired level of accessibility and inclusion. To this end, (i) the project objectives are defined, aligned with the spatial layout and curatorial strategy, (ii) the preferred users, and (iii) the key cognitive and motor tasks required during the visit (i.e., task analysis). The second phase concerns the integrated analysis of spatial intelligibility through the combined use of the two complementary predictive models. Within Space Syntax, the analysis involves the use of the pen-source software DepthmapX 0.8.0 (UCL Space Syntax, 2025). The first area of investigation concerns the exhibition rooms, in which spaces are modeled as nodes and connections. From this structure, it is possible to generate the visibility graph, from which the main indicators are calculated. First, connectivity, which measures the number of spaces immediately accessible from each node and provides an indication of its physical usability; second, visual integration (HH), which expresses the average visual distance from all other points in the spatial system and reflects the potential visibility and recognizability of each space. A second area of investigation concerns a more detailed analysis, dividing the spaces into a regular grid, which allows for a comparison of the local distribution of the same indicators, highlighting intra-space variations. Finally, agent analysis simulates flows based exclusively on the visibility of grid points, highlighting areas with greater or lesser traffic density based on the potential intuitive movement of homogeneous users. Within ABM, the analysis is based

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on the use of Anylogic 8.9.4 software (The Anylogic Company, 2025), a multi-method simulation platform available free of charge in the Personal Learning Edition (Borshchev, 2014). Following the modeling of the museum environments, an initial investigation focuses on the dynamic behavior of visitors throughout the entire visit. Using the Pedestrian Library, logical graphs can be constructed consistent with the task analysis (ideal vs free visit). The simulations produce density maps and movement analytics. Finally, a second, more detailed analysis concerns individual rooms to evaluate possible functional alternatives aimed at improving their usability. The third and final phase (Critical synthesis), in line with the need for a holistic understanding of accessibility as a generative ecosystem (Lauria & Ndrega, 2025), involves the integration of the results. A comparative assessment enables the identification of areas with low spatial intelligibility: spaces with poor visual integration, ambiguous routes, and nodes subject to congestion or low attractiveness. Finally, the integrated approach supports the definition of design directions geared toward inclusive wayfinding, in which both dimensions of usability (space and people) become essential parameters within an ergonomic framework for museum environments, useful for guiding the project towards more legible spatial solutions consistent with the diverse needs of users.

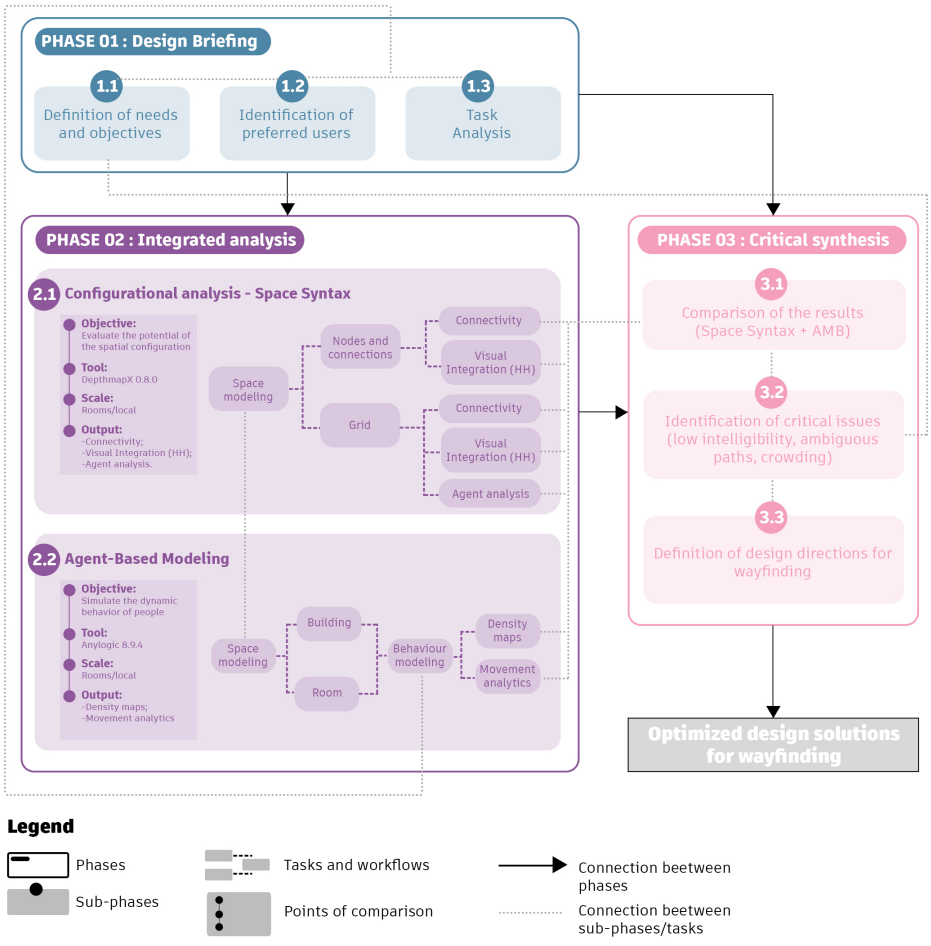

Figure 2. Methodological framework for museum wayfinding, structured in three phases: Design Briefing, Integrated Analysis (Space Syntax and Agent-Based Modeling), and Critical Synthesis, aimed at identifying critical issues and defining optimized, inclusive wayfinding design solutions.

EVIDENCE AND DESIGN DIRECTIONS FOR INCLUSIVE WAYFINDING

The experimentation, conducted within the “Amedeo Maiuri” Museum and structured across the three methodological phases, highlighted a set of evidence useful for defining design strategies aimed at spatial accessibility and inclusive wayfinding. The first phase defined the specific objectives of the

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wayfinding project, which included improving spatial intelligibility, fostering users' autonomy in perception, and reducing moments of decisional uncertainty. Attention was focused on the conscious use of architectural components as primary orientation resources, reducing reliance on redundant signage systems. Subsequently, preferred users were defined as those visitors for whom difficulty interpreting space could represent a significant barrier to cultural enjoyment: people with sensory or mild cognitive disabilities, elderly visitors, and individuals with low cultural literacy. On this basis, a task analysis was developed to break down the museum experience into specific cognitive and motor tasks. In the basement, after identifying the main entrance, users must locate the ticket office and navigate the vertical connections, preferring to use the new elevator. On the ground floor, tasks become exploratory, such as reading the thematic narrative, recognizing immersive rooms, and then reach the exit or the first floor. Finally, within the temporary exhibition, users must understand the thematic discontinuity and decide when to conclude their visit, preferring to return to the basement by elevator. At each level, specific cognitive junctions were identified, i.e., decision points where the visitor must interpret the space to make a directional or functional choice. These junctions constitute discrete behavioral units, the combination of which describes the user's action sequence along the entire journey. The second phase involved the integrated application of simulation tools to assess spatial intelligibility. First, the configurational analysis (Figure 3) allowed us to analyze the space on two scales: by individual rooms (nodes and connections) and by detailed areas (grid). At the first scale, connectivity (Figure 3a) shows, in the basement, greater connectivity of the distribution spaces (entrance and corridors towards the stairs and elevator), while the conference room is less connected. On the ground floor, Rooms 2 and 6 stand out for their high values, while the two immersive rooms and Room 9 are less connected. On the first floor, the "Maiuri" Room shows the highest values, without evident critical issues. Visual integration (HH) (Figure 3b) shows the main corridor towards the stairs as the most integrated spaces in the basement. On the ground floor, the highest values are concentrated in Rooms 2, 6, and 10, while the two immersive rooms and Room 9 show, again, critical values. The first floor shows the same values as the first analysis. Delving deeper into the scale, the analysis (Figure 3c) shows high connectivity in the basement along the entrance-ticket office-cafeteria axis, with decreasing values toward the connection leading to the new elevator. On the ground floor, the entire exhibition route is well connected, apart from the immersive rooms and Room 9. The first floor shows no significant anomalies. Visual integration (HH) (Figure 3d) confirms these trends. Finally, validation using Agent Analysis (Figure 3e), which simulated the entry of 50 agents at each level, confirms the disadvantages of the route to the elevator, the immersive rooms, and Room 9. Second, ABM allowed us to simulate the dynamic behavior of visitors, again on two observation scales. The first investigated the scope of the plan and focused on two types of behavior: an "ideal" visit, adhering to the pre-established itinerary, and a "free" visit, in which only entrances and exit points are defined. The second scale instead examined a single room, with the aim of analyzing the spontaneous distribution of visitors, the order in which they viewed the artworks, and preferential exits.

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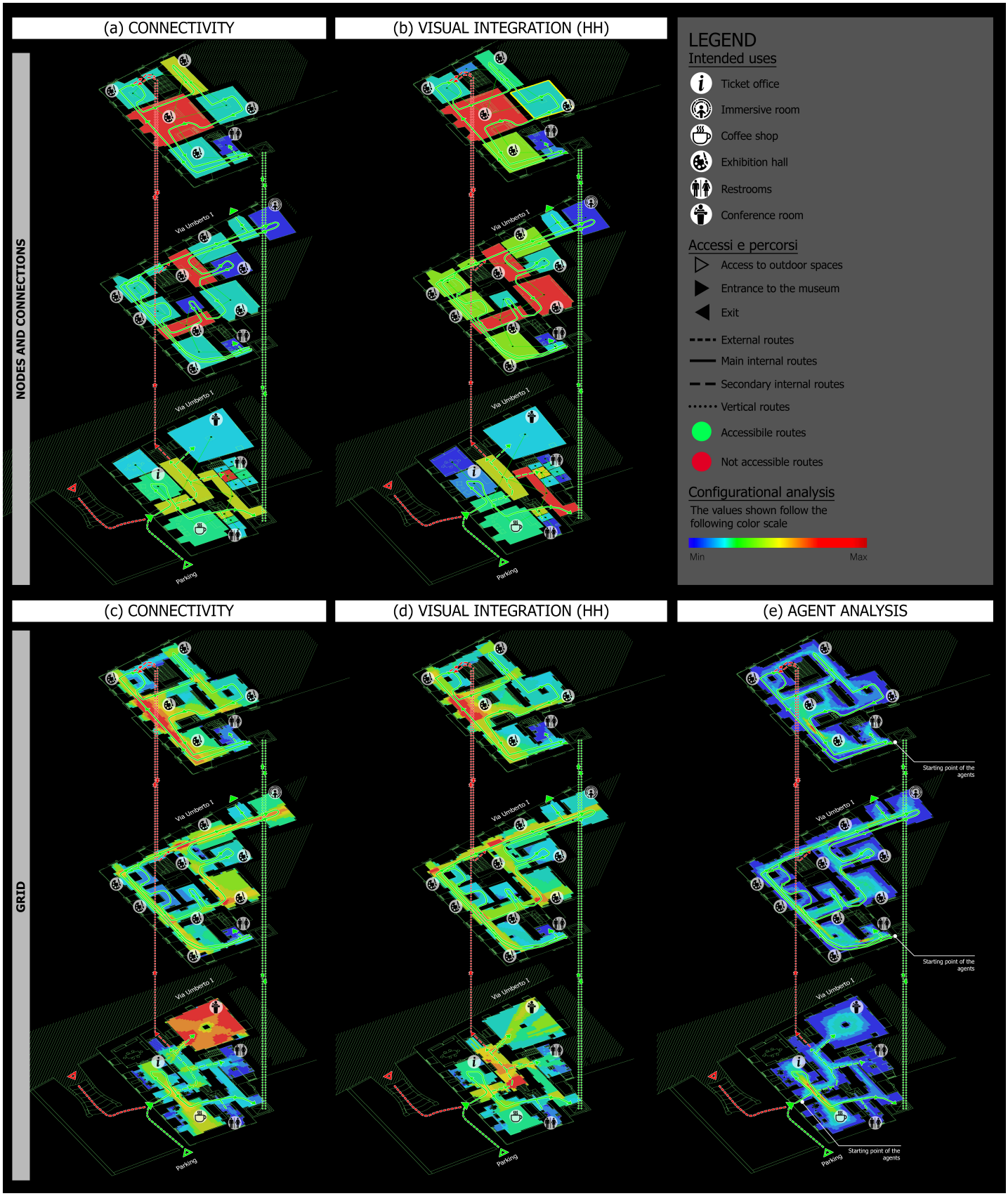

Figure 3. Results of the configurational analysis applied to the "Amedeo Maiuri" Museum at the two investigation scales. The nodes-and-connections model illustrates (a) connectivity and (b) visual integration (HH), while the grid-based analysis shows (c) connectivity, (d) visual integration (HH), and (e) agent analysis.

For the first scale, we provide the example of the ground floor (Figure 4), considered the most critical in terms of distribution and orientation. Modeled the space (Figure 4a) and the two behavioral profiles (Figure 4b,c), two simulations were conducted, involving 50 agents and recording the results at

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three time intervals (15, 30, and 60 minutes): density maps (Figure 4d) and visitor distribution graphs for each room (Figure 4e). In the ideal visit profile, the density maps show low attendance in Rooms 4,5 and in both immersive rooms.

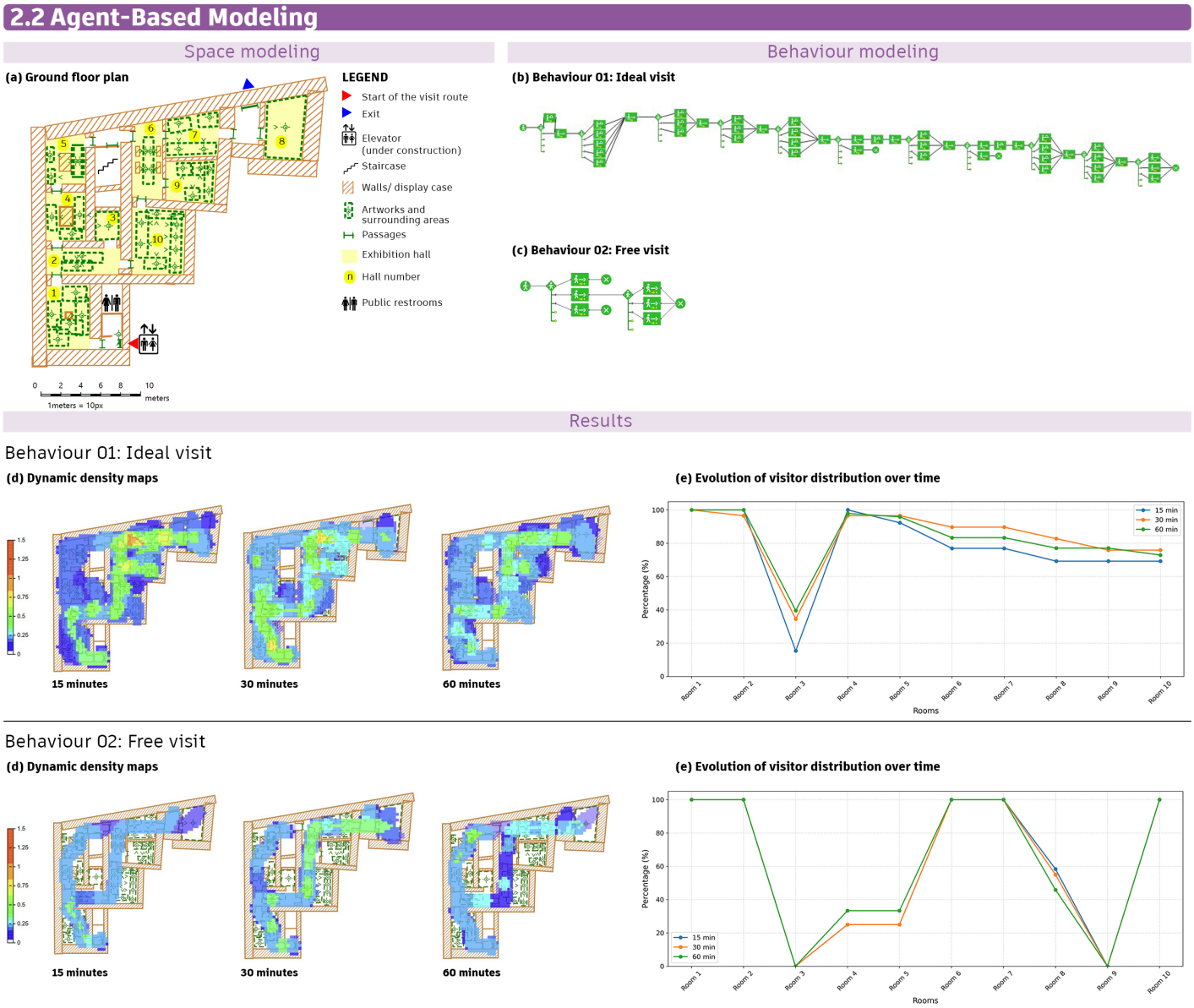

Figure 4. Agent-Based Modeling applied to the ground floor of the "Amedeo Maiuri" Museum: (a) the space model, the behavioral graphs for (b) the ideal visit and (c) the free visit and the simulation results in terms of (d) dynamic density maps at different time intervals and (e) the evolution of visitor distribution over time for both behavioral scenarios.

The graphs confirm full visibility in the initial rooms (1 and 2), with a progressive decrease in the subsequent ones. Room 3 (the immersive room dedicated to Palazzo Campanari) is particularly critical. In the case of a free visit, the maps show a total lack of interest in Rooms 3 and 9. Furthermore, after passing Room 2, most visitors tend to head right (Room 10) rather than left (Room 4). The distribution graphs confirm this trend, which remained stable across the three periods analyzed. For the second scale, we provide the example of the "Maiuri" room on the first floor, the most significant of the entire itinerary (Figure 5a). The room, currently characterized by an important decorative apparatus (Figure 5b), will house heterogeneous artworks in the exhibit project, arranged according to different spatial logics in relation to the entrances, circulation axes, and fields of vision. As shown in the plan (Figure 5c), Artwork 1 (Context of the Porta Nocera Necropolis: copy of a cast and

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columelle) is placed marginally with respect to the main trajectories of movement; Artwork 2 (19th-century marble top with utensils from the House of Menander) occupies a central position in the space; Artwork 3 (Documentary “Pompeii. Twenty Centuries Later”) is arranged along one of the longitudinal walls, near an opening; while Artwork 4 (Frescoes of Bosco Reale; Trapezophore Royal II) is placed on a lateral wall visually accessible from both entrances. This configuration makes the room particularly suitable for evaluating how visibility, proximity to access points, and centrality influence the observation sequence and visitors' movement choices through ABM (Figure 6). Modeled the environment (Figure 6a) and the behavioral combinations of the 50 agents (Figure 6b), the same three time intervals were observed, and the results were expressed in the form of density maps (Figure 6c) and piecharts of the order of the visited works (Figure 6d,g) and the chosen exits (Figure 6h). Density maps show a homogeneous distribution with a concentric trend.

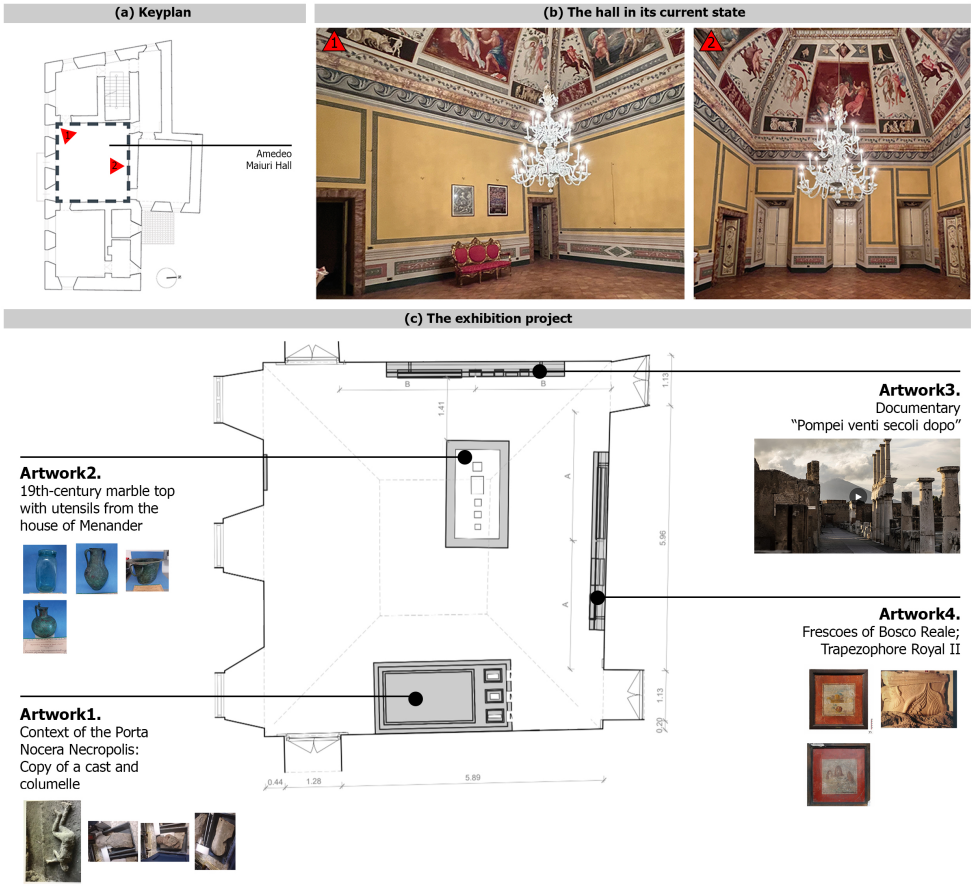

Figure 5. The “Maiuri” Room: (a) Key plan of the first floor showing the location of the room; (b) images of the room in its current state and (c) the exhibition project with indication of the artworks analysed in the ABM simulation.

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2.2 Agent-Based Modeling

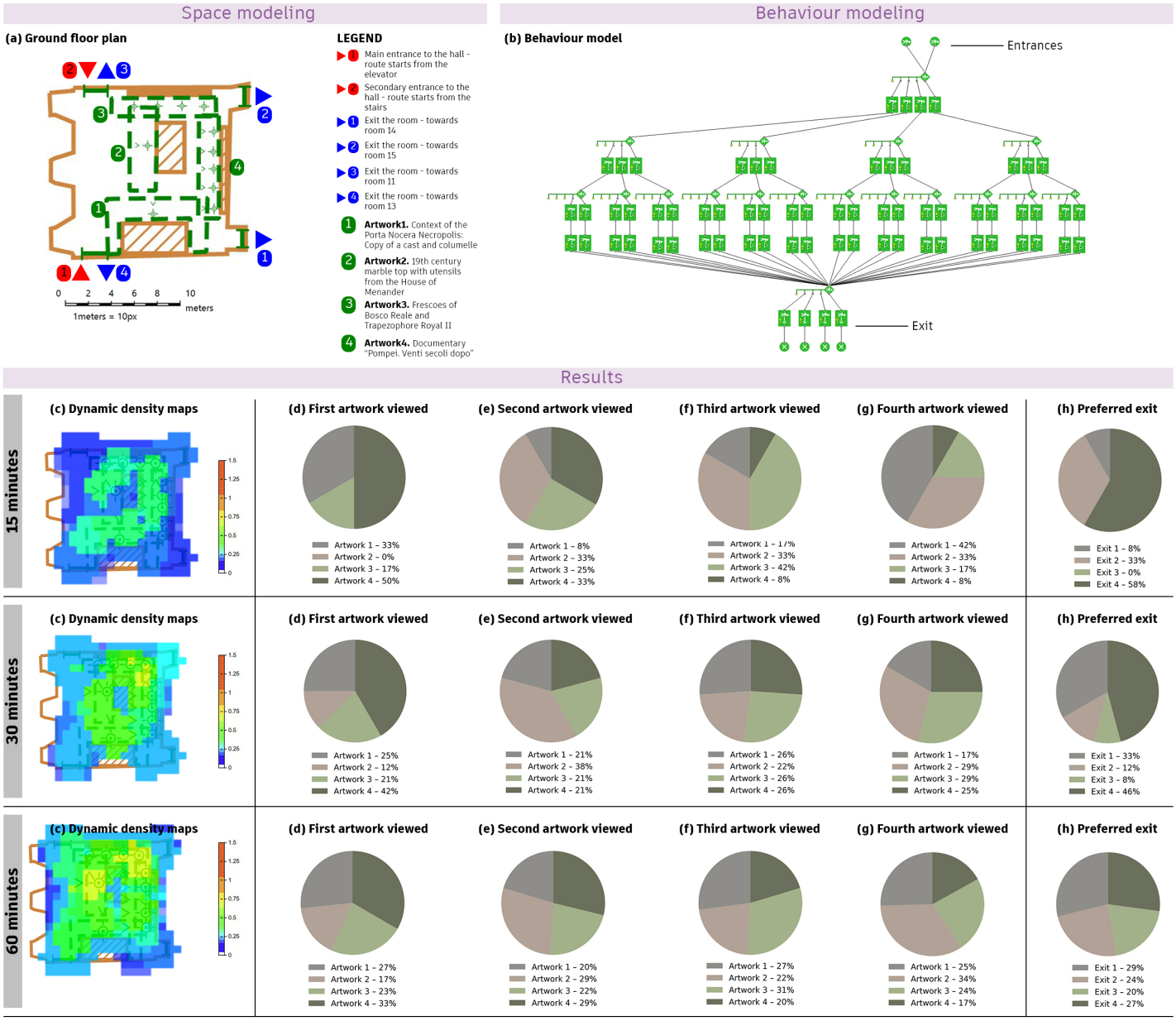

Figure 6. Agent-Based Modeling applied to the "Maiuri" Room: (a) the space model, (b) the behavioral model, and the simulation results in terms of (c) dynamic density maps at different time intervals, (d–g) the sequence of artworks viewed (first to fourth), and (h) the preferred exit.

The order of visit graphs indicates that Frescoes and Trapezophore (Artwork 4) Artwork, immediately visible from both entrances, systematically constitute the first point of attention, while the central work (Artwork 2) is never chosen first in the first 15 minutes. As the second artwork, there is initially a balance between these two (33%), but at 30 minutes the central one prevails (38%), with a re-balance at 60 minutes (29%). Context of the Porta Nocera Necropolis (Artwork 1) is the least viewed at this stage. The third most viewed work is the multimedia content (Artwork 3), while Artwork 4 become the least viewed in this intermediate phase. As the last artwork viewed, Artwork 1 initially prevails, but at 60 minutes Artwork 2 is most frequently seen last. As for exits, after 15 minutes over half of the agents (58%) use Exit 4, while Exit 3 is never chosen. At 30 minutes, the trend rebalances slightly; at 60 minutes, preferences are more evenly distributed, with a slight prevalence for Exit 1, which leads to room 14. In the third and final phase, comparing the results of the two models highlighted a significant consistency between the spatial structure and user movement patterns. Specifically, environments characterized by low

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connectivity and visual integration in the Space Syntax were found, in the ABM simulations, to be often excluded from the itineraries, both in the ideal and free modes. This allowed us to identify critical areas: in the basement, the connection leading to the elevator and on the ground floor, the immersive rooms and Rooms 4,5, and 9. The situation appears more balanced on the first floor, where the linearity of the path favors a more homogeneous distribution, as confirmed by the analyses carried out in the "Maiuri" Room. Based on this evidence, it was possible to define a series of design directions to improve the museum's inclusive experience. In the basement, for example, to effectively direct visitors to the new elevator, visual direction could be strengthened by placing adhesive floor markers or installing lighting fixtures that emphasize perspective depth. Furthermore, reducing distractions along alternative routes (such as those leading to the stairs) can further facilitate intuitive navigation. On the ground floor, immersive and low-traffic rooms require greater architectural emphasis: gates highlighted by color or light variations and multisensory devices can help make these spaces more recognizable and attractive. Finally, analysis of the "Maiuri" room suggests that, even at the microscale, the intelligibility of exhibits and the position of gates influence visitor behavior. The visual focus of key works and gates should be emphasized through focused lighting, architectural elements that guide the gaze, and installations that facilitate sensory accessibility. In summary, the critical synthesis phase demonstrated how spatial intelligibility, if properly designed, can become the primary driver of inclusion in cultural venues. The integration of layout and behavior not only allows us to identify the weak points, but also provides the tools to transform them into design opportunities, capable of enhancing the visitor experience in its plurality. The case study of the "Amedeo Maiuri" Museum demonstrates, in this sense, the potential of an evidence-based approach in defining truly effective accessibility strategies that can be replicated in similar contexts.

CONCLUSIONS AND FUTURE DEVELOPMENTS

This paper highlights the operational value of an integrated approach between Space Syntax and ABM as a decision support tool for designing accessible and cognitively readable museum environments. The complementarity of the two models has provided a dynamic, complex, and measurable picture of the actual modes of interaction between space and visitor. The ability to identify areas of low visual integration and critical decision points, simulate different visitor profiles, and pre-test the effectiveness of design solutions represents a concrete advantage for implementing wayfinding strategies geared toward inclusion, reducing cognitive load, and enhancing the perceptual autonomy of each user type. From this perspective, the proposed methodology is configured as an evidence-based design tool, replicable in similar contexts and integrable into broader processes of digital transformation of cultural heritage. The limitations of this study are primarily due to the small scale of the case study, which, while allowing for precise control of spatial and behavioral variables, does not yet allow for a full test of the framework's robustness in museum contexts of greater size and morphological complexity. A further limitation concerns the difficulty in defining the agents' behaviors, which is inevitably simplified compared to the actual heterogeneity of potential visitors, whose variability in terms of skills, familiarity with the spaces, and cognitive abilities makes comprehensive modeling difficult. Finally, the framework has not yet been subjected to post-occupancy validation, which is an essential step in verifying the correspondence between simulated results and actual

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behaviors. This validation may be initially conducted in a virtual environment and, subsequently, after the implementation of the wayfinding design solutions, through the application of Post Occupancy Evaluation (POE) methodologies, in order to consolidate the model's predictive reliability through direct user feedback. In any case, the framework's potential suggests future developments that include extending its application to more complex museum contexts, refining behavioral models through a more detailed characterization of user profiles, including with the support of the International Classification of Functioning, Disability, and Health (ICF), to represent behaviors in relation to users' different functional conditions and their modes of interaction with the space, and studying ways to integrate it with post-occupancy empirical validation procedures. Further future developments include integration with BIM-based environments for the simulation and validation of alternative scenarios, aligned with new paradigms for using PEBA as an iterative digital tool across the entire museum lifecycle. Finally, the use of artificial intelligence systems and IoT (Internet of Things) sensors would allow learning from behavioral data and generating adaptive and personalized pathways, strengthening the proposed method's potential as a digital infrastructure for inclusive museum design.

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SHORT BIO

Gianmauro Romagna, Architect, is a Research Fellow at the Institute of Cognitive Sciences and Technologies of the CNR in Rome (Italy). His research mainly focuses on decision-support tools for programming and design in cultural and healthcare fields and, more generally, in complex decision-making contexts, within the broader framework of digital management of the built environment.
gianmauro.romagna@istc.cnr.it

Teresa Villani, Architect and PhD, is an Associate Professor of Architectural Technology at the Department of Planning, Design, and Architectural Technology, 'Sapienza' University of Rome (Italy). She conducts research on technological and social innovation in design for the community, focusing on spatial usability, environmental communication and wayfinding, with particular attention to inclusion design and sustainability.
teresa.villani@uniroma1.it

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