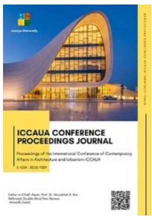

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The Impact of Landmarks'' Visibility on Children's Navigational Performance: A Visual Graph and Behavior Analysis in Bahraini Primary Schools

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Abstract

Architectural Characteristics of school-built environments significantly impact students' learning experiences, perceptions, and behaviors. While existing literature predominantly focuses on adults' perceptions, research on navigational performance often overlooks the critical role of visual landmark visibility in fostering students' self-confidence, safety, and well-being. Therefore, this study addresses the gap between theoretical frameworks and practical applications by examining the impact of landmarks' visibility on navigational behavior, aiming to improve the spatial experience for primary school students in Bahrain. The study integrates Space Syntax through Visibility Graph Analysis to assess landmark visibility across two primary school buildings. It also employs behavior analysis through descriptive frequency count to evaluate students' confidence levels and confusion during the navigational process. The qualitative and quantitative results reveal that landmarks' visibility significantly impacts navigational performance, offering recommendations to designers and policymakers to curate school designs that enhance students' learning experience while promoting their mental and physical well-being.
Keywords: Navigational Performance; Primary Schools; Visual Landmarks; Visual Graph Analysis; Behavioral Analysis.

1. Introduction

Navigation is the art and science of moving safely and effectively from one location to another (Trullier et al., 1997). It is a sensory system of visual (sight), vestibular (balance), and proprioceptive (sense) information about the environment and constitutes spatial orientation as a multi-sensory process (Ekstrom et al., 2018). From the visual perspective, effective navigation involves perceiving a space, comprehending it, and making swift decisions about the subsequent actions. (Amen, Afara, and Nia 2023; Amen and Nia 2020) There are two separate representations of visual space; the first is the cognitive or the "what" system, which interprets visual data for purposes such as pattern identification and everyday visual perception. The second is the sensorimotor or the "how" system, which manages behavior led by vision (Bridgeman, 1999). Other researchers described it as the connection between the information or data perceived from the environment "input" influencing the "out-put," which are the actions made by users (Jamshidi & Pati, 2021).
While signages do not solve wayfinding problem completely, especially with complex multi-level spaces (O'Neill, 1991) and in case of emergencies (Vilar et al., 2014), landmarks play a crucial role in spatial orientation due to their unique and memorable characteristics (Hassan et al., 2024). Landmarks are visual tangible objects that serve as reference points within a space, helping users to form mental images and navigate more efficiently (Lynch, 1960). According to Yesiltepe and her collogues, "having knowledge of an environment tend also to include having knowledge of its landmarks" (Yesiltepe et al., 2020). Though, for landmarks to effectively support navigation, they must be clearly visible within the environment, as "invisible landmarks cannot be salient" (Yesiltepe et al., 2020). Prior research has shown that the use of landmarks significantly reduces navigational errors (Ruddle et al., 2011). However, the existing literature has demonstrated a focus on landmarks' visibility in adult population, leaving a noticeable gap on how these spatial cues are perceived and utilized by children.
Given that children spend most of their waking hours at school (Rezaei Liapaee et al., 2020), schools' physical design and layout are central to how children experience, perceive, and behave within the space (Manca et al., 2020). These institutions have become the principal source for socialization and intellectual development, directly contributing to children's experience. In addition to induce stress, heighten anxiety, and create confusion (Vieites et al., 2020),

navigating through a complex indoor environment for children, such as primary schools, can creates safety problems, reduces independence, interferes with study, and increases social isolation (Gentle et al., 2024; Giraldi et al., 2019; Wu et al., 2008).

Despite the importance of spatial navigation for children's independence, learning, and well-being, limited research has explored how architectural elements, particularly landmarks, affect children's wayfinding in primary schools. This issue is even more pronounced in Bahrain and the Gulf region, where studies applying theoretical frameworks such as Kevin Lynch's to school environments are virtually absent. Therefore, to offer schools' designers and decision-makers recommendations on how to incorporate effective landmarks in school environments, this study aims to improve the navigational experience in primary schools, focusing on exploring the impact of visual landmarks' visibility on children's navigational behavior (Figure 1). Consequently, the study investigates three main objectives:

1. To explore the role of landmarks as a wayfinding cue in children's perception.
2. To assess the visibility of visual landmarks in schools in Bahrain.
3. To evaluate children's navigational behavior in schools in Bahrain.

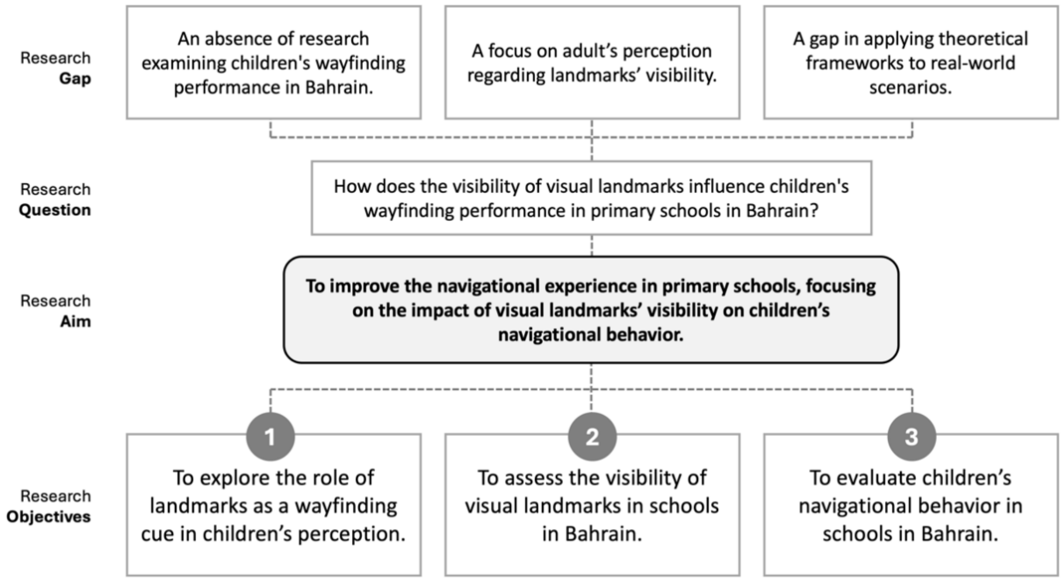

Figure 1. Research Plan – gap, question, aim, and objective (Developed by Author).

In this context, an extensive literature review in such areas as landmarks as wayfinding cues, visual landmarks, and children, children's perception of their school, and Visual Graph Analysis as a tool. The methodology utilizes a mixed-method approach combining spatial layout, visual graph, and behavior analysis across two primary school buildings in Bahrain. The study findings will offer school designers and decision-makers recommendations on ensuring effective navigational performance among children in Bahraini schools. These recommendations will help curate school designs for children by incorporating effective landmarks that enhance their learning experience, reflecting on their self-confidence, safety, and well-being.

2. Literature Review

The term "way-finding" was initially introduced by Kevin Lynch in his 1960 book "The Image of the City." In his book, he defines wayfinding as purposefully solving the problem of reaching a destination from an origin point (Lynch, 1960). As part of the physical space, Lynch defined five main elements that affect wayfinding, including landmarks, paths, nodes, edges, and districts. According to Montello and Sas (2006), navigation consists of wayfinding and locomotion. To distinguish the two, Montello identified locomotion as moving on a route, while wayfinding involves determining a route toward a destination (Montello & Sas, 2006). On the other hand, Passini defined wayfinding as locating one's way to a destination by addressing spatial problems that require information processing, decision-making, and execution (Arthur & Passini, 1992). While wayfinding sounds like a seemingly simple task, it involves complex cognitive processes (Tversky, 1993).

To successfully navigate complex spaces, an individual must first become aware of their surroundings by gathering data from the environment. A person may feel lost during wayfinding if this information is irrelevant or confusing (Hidayetoglu et al., 2012). By understanding the complex relationship between environmental design elements, designers can offer environmental information that is easily observable, distinguishable, and adaptable by users. While various elements, such as color, light, and spatial arrangement, work together to shape a user's perception of space; studies showed that landmarks effectively reinforce navigation as they serve as stable and recognizable reference points that users can anchor to. Due to their unique and memorable characteristics, people rely on landmarks when orienting and communicating routes (Hassan et al., 2024). According to Yesiltepe and her collogues, "having knowledge of an environment tend also to include having knowledge of its landmarks" (Yesiltepe et al., 2020). Therefore, it is essential to understand the role of landmarks in wayfinding tasks and how children perceive them.

2.1. Landmarks as Wayfinding Cues

According to Siegel, landmarks are notable environmental elements that complement or contrast with the surrounding environment (Siegel & White, 1975). Moreover, Golledge emphasized that landmarks can be man-made or natural objects that are fashioned by culture and fit into their surroundings (Golledge, 2003). As a result, landmarks define the features of a place and create geographic routes by creating points of departure or arrival as well as pathways for travel (Ghassemzadeh, 2016). According to Lynch (1960), landmarks are tangible objects that serve as reference points. Consequently, Ghassemzadeh elaborated that any physical element aiding the orienting process can be considered a landmark.

There are two types of landmarks: local landmarks and global landmarks. These landmarks classifications are based on their level of visibility (Yesiltepe et al., 2020). Global landmarks, such as mountains or skyscrapers, are commonly described as features or items in a landscape that are visible from various perspectives and distances (Lin et al., 2012). On the other hand, local landmarks, such as trees or signages, are described as being visible only from specific directions and from a restricted region (Steck & Mallot, 2000). Moreover, Ruddle et al. (2011) hypothesized that using global and local landmarks in an environment reduces users' navigational mistakes and errors (Ruddle et al., 2011). However, on a building scale, local landmarks are more important than global ones and are essential for determining route directions, especially at decision points (Arthur & Passini, as cited in Hassan et al., 2024). This highlights how vital unique and memorable features are for efficient wayfinding and spatial communication.

In contrast to outdoor spaces, the enclosed nature of indoor spaces differs with some unique characteristics, such as the smaller size, information volumes included, and complexity of the structure (Jeamwatthanachai et al., 2016). Although proper signage adds advantages to navigating a complex indoor environment, using a building's distinctive characteristics, such as textural information, can reduce users' cognitive load (Raubal, 2001). However, the impact of landmarks on users' wayfinding experience is shaped not only by the landmarks' intrinsic characteristics but also by the users' perceptual and cognitive interpretations. Studies show that landmark effectiveness can vary according to user familiarity, cultural context, gender, and age, influencing how individuals identify and interpret navigational cues. For instance, visually prominent or contextually relevant landmarks within a specific environment are more likely to be recognized and used for orientation. Therefore, to understand what children recognize as landmarks, it's essential to consider how they interpret environmental cues, as developmental and sensory interactions with the space shape their perception.

Not all landmarks are considered salient, but a landmark must be visible in order to be considered salient; "an invisible landmark cannot be prominent" (Yesiltepe et al., 2020). Sorrows and Hirtle (1999) contributed significantly to the landmark saliency (Sorrows & Hirtle, 1999). They distinguished three distinct landmarks for both actual and virtual settings: structural, cognitive, and visual. By definition, a visual landmark is a physically noticeable object (because of its size, shape, material, color, etc.); a cognitive landmark is associated with the meaning of an object (i.e., its cultural or historical significance or general knowledge of the object); and a structural landmark is associated with the significance of the object's location. Because they stand out from their surroundings, visual landmarks are highly memorable.

2.2. Visual Landmarks and Children

While many neurological studies focused on comprehending this cognitive map in adults (Burles et al., 2020), psychologist Jean Piaget in 1967 explored the development of this theory in young children. Piaget's theory states that spatial knowledge evolves throughout a person's life, influencing the development of navigational skills (Piaget, 1976). Based on his theory, children naturally develop insights through their interactions with their environment, often learning independently without guidance from older peers or adults. Their intrinsic curiosity drives them to explore and understand more without external rewards, underscoring the self-motivated nature of their learning. The theory expressed the development in four categories depending on the child's age, including the sensory-motor period, pre-operational period, concrete operational period, and formal operational period.

According to the literature review by Türel and Ayşe Gür, other psychologists expanded this theory to incorporate the idea that children's spatial knowledge varies depending on how they interact with their environment and how they perceive it spatially (Türel & Ayşe Gür, 2019). As a result, children's interactions with their environment have a significant impact on how they grow cognitively. Furthermore, cognitive mapping does not emerge until the age of seven, according to a study on youngsters, and their "mental representation" of their environment is weaker than in adults (Lehnung et al., 2003). This implies that youngsters under the age of seven are incapable of using spatial information gleaned from their surroundings to solve navigational challenges. According to other research, the cognitive growth milestone occurs at age 8 (Burles et al., 2020).

A study investigated the role of landmarks in children's journey from home to school. Ghassemzadeh's study (2016) findings indicate that children's cognitive development, especially during the concrete operational stage, offers insights into how they process spatial and environmental cues, focusing on topological and projective qualities. Study results highlight that urban buildings and visual elements significantly impact children's spatial perception and wayfinding, as children tend to unconsciously rely on visual cues like signs and landmarks to navigate. This reliance indicates that environmental features are crucial in shaping how children interpret and move through space.

Many physical elements are found to affect children's navigational experience significantly. Researchers investigated the role of color, texture, and nature as landmarks to aid children in navigating a space. Fidan et al.'s (2021) study used interviews and drawing tasks with six children to understand how Kevin Lynch's wayfinding elements can be combined with biophilic design to improve the navigational experience in primary school (Fidan et al., 2021). The research found that students frequently preferred natural elements representing "district" and

“landmark” as they are more prominent and memorable. In addition to providing a less anxiety-provoking space, the biophilic design offered children a unique and outstanding point of interest to improve their spatial awareness.
On the other hand, GÜNEŞ and OLGUNTÜRK’s (2020) study examined the role of colors in children’s spatial tasks compared to adults (GÜNEŞ & OLGUNTÜRK, 2020). A physically structured experiment included a route with six decision points, where colored or gray boxes were placed to serve as visual cues. Using a “Pointing Task” with one hundred children (aged seven and eight), the study suggested that children who saw colored visual cues performed better than those who saw gray cues. Therefore, colors are a significant factor in the children’s ability to wayfinding despite the impact of alternative influencing variables, like individual differences, prior experience, or environmental distractions intertwined with spatial navigation. Both studies by Fidan et al. and GÜNEŞ and OLGUNTÜRK focused on interventional experiments, where elements are added to understand elements’ impact on children’s perception. However, a holistic view of children’s navigational ability in their school depends on their perception of their surroundings’ features and characteristics.

2.3. Children’s Perception of Their School

The physical elements forming the structure of the school are primary factors influencing children’s spatial perception, which contributes to the construction of mental images. While Türel and Ayşe Gür have investigated the physical elements of the two schools to understand their impact on children’s cognitive development through different stages, Rezaei Liapaee and colleagues chose to focus on students’ interaction with physical characteristics and how other features evoke mental images depending on student’s perception (Rezaei Liapaee et al., 2020). Both studies focused on students drawing a map from a point to the destination in their mind and found that texture, color, abstract symbolization, and contrast between scales work as visual stimulants to improve children’s spatial awareness.
However, Türel and Ayşe Gür’s study aimed to examine the linkage between the environment and mind development. Researchers analyzed 172 sketches according to dimensions, including topologic, projective, and metric-imaginative space. After comparing findings from different schools to identify patterns and differences based on the physical characteristics of the school environments, the study findings revealed that the physical characteristics and spatial organization of primary school buildings significantly contribute to children’s physical and cognitive development. The study pinpointed environmental elements, including size and stimulant material, as having favorable effects on children’s awareness of space and behavior.
In contrast, Rezaei Liapaee et al.’s study in 2020 researched an effective stimulant attribute to form the best cognitive and mental map of seven- to twelve-year-old children. The study included 168 sketch maps drawn by students from different grade levels in two primary schools in Iran. The results show that children between 7 and 8 years old develop navigational mental images significantly by playgrounds, those between 9 and 10 years old are significant with green areas, and those aged from 11 to 12 by the signs. It may be that although under 9s are too young to have developed emotional ‘nostalgia’ for playtime in the youngest group, they will always have a ‘natural’ or untrained understanding of wayfinding from ages about 9-10 (and over) and aged between 11 to 12 they may be starting to form a sense of some of the components comprising the concept of wayfinding. The study also found no age-related differences in wayfinding, and the variances in their cognitive maps might be homogenous. Results revealed that changes in scale, bright colors, architectural features, and the use of textural and graphic elements appropriate for children can improve wayfinding performance within educational environments.
In general, efficient wayfinding is an essential skill for children, especially in the school setting, where they start to explore independently. Landmarks play a critical role in this process; however, their effectiveness in aiding navigation diminishes significantly if global and local landmarks aren’t visible. According to Yesiltepe et al. (2020), landmark saliency is related to their visibility. For children, the ease of locating these visual cues can enhance their confidence and autonomy in exploring their environment. Therefore, ensuring landmark visibility within school layouts is key to fostering accessible, child-centered spaces that support wayfinding and spatial learning. Additionally, assessing the capability of design software and programs to evaluate landmarks’ visibility accurately can inform evidence-based design improvements, ensuring these navigational aids meet children’s needs effectively.

2.4. Visual Graph Analysis (VGA)

Space syntax theory is based on the rejection of the metric properties of space. It is based on the spatial configuration that is represented by topological data. As a strategy, space syntax analysis helps researchers understand how people interact, move around, and navigate inside a designed space. In addition to their communication systems (van Nes & Yamu, 2017), During the design process, space syntax analysis aids researchers in comprehending the intricate relationships between different elements within a given area that might not be immediately obvious or observable. Spatial configurations are explored using methods like Axial Map, Convex Map, and Isovist Map, which reveal spatial hierarchies, patterns of connections, and possible obstacles in space (Hillier & Hanson, 1989). Designers can characterise the possible effects of design options on human experiences by measuring user-centred elements using spatial attributes through the use of space syntax analysis. The study of pedestrian mobility (Khorsheed & Goriel, 2021), building navigation clarity and readability (Obeidat & Rashid, 2017), and the openness and accessibility of educational structures (Mohammed et al., 2022) have all made use of space syntax. Other studies have used space syntax theories to investigate the connection between wayfinding systems and user behaviour (Chen et al., 2021) and public perception and spatial layout (Soares et al., 2020).

Originating from space syntax, Visibility Graph Analysis (VGA) is a tool for evaluating the inter-visibility connections within structures or urban networks. VGA is an architectural theory utilized to create a visibility graph within the open space of a layout (Turner et al., 2001). Researchers also utilized VGA to investigate the visual connectivity of street patterns and the itineraries taken by the children (Fares & Bougdah, 2023) and to explore the impact of school layouts on students' learning, behavior, and interactions within educational environments (Ahmad & Ullah, 2024). Overall, studies in space syntax VGA highlight the method's effectiveness in gaining an in-depth configuration analysis within an educational built environment from the users' perspective. Understanding human behaviour in the built environment can be improved by using various qualitative methods, such as interviews and observations that are in line with space syntactic methodologies (Lochmiller, 2021).

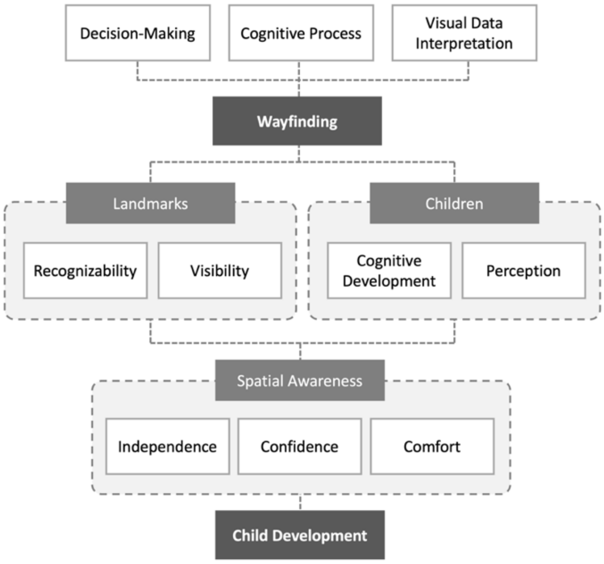

Figure 2. Hierarchical Structure of Wayfinding Concepts: Illustrating the role of landmarks in supporting effective wayfinding child development within educational environments (Developed by Author).

In conclusion, as illustrated in Figure 2, the wayfinding concept, as introduced by Kevin Lynch, emphasizes that navigating space requires more than physical movement; it involves cognitive processing, decision-making, and interpreting spatial cues to reach destinations. Effective wayfinding relies on carefully designed elements, such as landmarks, that make the environment understandable and navigable. By integrating visible and memorable landmarks, designers can help individuals, including children, feel oriented and confident within complex spaces like schools. This underscores the importance of designing spaces that support intuitive navigation and utilizing tools to assess the visibility and effectiveness of these wayfinding cues to enhance user experience and promote spatial awareness.

For children during cognitive abilities development, landmarks become especially crucial in school environments, where visibility and recognizability aid them in building spatial understanding and confidence. The effectiveness of these navigational cues is influenced by the landmarks' intrinsic features and children's perceptual and cognitive development. Research highlights that various physical sensory cues and visual stimulants shape children's perception of school environments. These elements support children's navigational skills, especially as they progress through different cognitive developmental stages.

3. Research Methodology

Results from the literature review suggest a complex and highly variable relationship between visual landmarks as a navigational cue and children's perception as the primary users of schools. Both factors need to be explored to explore the impact of visual landmarks' visibility on children's navigational behavior. By integrating both qualitative and quantitative methods, the study benefits from a comprehensive data collection process (Creswell & Creswell, 2016). The literature review allowed the study to explore the role of landmarks as visual cues in children's perception. On the other hand, techniques used to understand the impact of landmarks visibility on wayfinding behavior were behavioral analysis through observation and spatial analysis through VGA across two school buildings in Bahrain. Due to the context-dependent nature of the study, this case study approach is critical to provide a comprehensive understanding of the interrelationship between landmark visibility and navigational behavior.

The case study approach enables an in-depth examination of a particular phenomenon within its natural context, which can create thick descriptions of the determinants influencing that phenomenon (Yin, 2017). This approach captures complexity where context matters to an essential extent for what happens. The focus on single instances helps the researchers to qualitatively capture how varying entities interact in each setting, producing an understanding frequently lost through expansive approaches (Stake, 1995). Therefore, the case study approach allows for a deep examination of the unique architectural and design elements that influence navigation, providing a comprehensive understanding of how specific spatial features and design strategies impact wayfinding. By adopting a case analysis approach, this study primarily investigates architectural features and wayfinding strategies implemented by two school buildings in Bahrain.

The two buildings were selected due to the difference in their complexity. Building 1 showcases a direct and straightforward linear circulation, with one corridor overlooking the schoolyard from one side and classrooms lined up on the other (Figure 3). Due to the similar layout in all three building floors, only the ground floor was selected for this study. While building 2 also has a linear circulation, the path is not direct, creating zig-zag turns and increasing the complexity of the layout (Figure 4). The contrasting complexity level of the selected buildings allows for a comparative result in relation to children's navigational behavior.

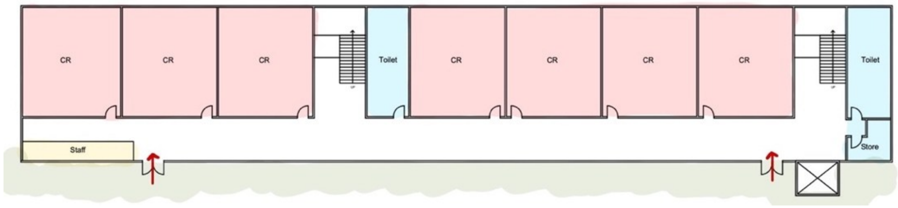

Figure 3. Floor plan of Building 1 (illustrated by Author).

Figure 4. Floor plan of Building 2 (illustrated by Author).

The spatial analysis involves studying the physical layout of the space by examining paths, nodes, and landmarks. Landmark visibility is systematically measured through Visibility Graph Analysis (VGA). This will be done through the isovist field, one of the space syntax analysis methods using DepthmapX software. The isovist analysis, or VGA, is primarily used for spatial orientation purposes (Van Nes, 2011) as it helps analyze the degree of visibility of elements within a building or urban area (Maina & Audu, 2016; Maina, 2014). The DepthmapX software operates on a range of scales, with the primary objective of linking open spaces in a floor plan through overlapping or intervisibility to analyze the resulting network graph analytically. The isovist view generates a color-coded diagram where blue indicates low connectivity and red indicates high visual connectivity. Prior to utilizing the software, a floor plan map of each building is drawn and carefully annotated to indicate the location of all visual landmarks (e.g., LM1, LM2, LM3, etc.). Landmarks are selected due to their visual characteristics, contrasting with the surrounding environment and their location within a decision point or node. The floor plan focuses on the building circulation and public corridors for students, excluding admin and staff areas. Overlapping the annotated map with VGA analysis allows the study to indicate the level of visibility of each landmark within the school buildings.

Data regarding behavior are gathered through observation to provide objective and informative data about children's navigational behavior. To ensure naturalistic observation, the researcher covertly records every behavior from pre-selected vantage points to prevent interfering with the children's movements. At each indicated landmark, the researcher stood for five minutes to document 10 children's behavior. To avoid overlooking subtle behaviors, an activity log will be used during the observation to ensure robust documentation and to mitigate any potential oversight. The gathered data are then analyzed through descriptive frequency count to document children's movement patterns, landmark interactions, decision points, and distractions and detours (Table 1). Results will then be compared between the two selected buildings.

Table 1. Example of the activity log for landmark 2 in Building 2.

Building: 2				**Landmark Code:** LM2		
Time	**Student no.**	**Movement Pattern**	**Landmark Interaction**	**Decision point reaction**	**Distraction & detour**	**Note**
10:25 am	S1	Straight to classroom	Glanced at the landmark briefly	Quick decision, no hesitation	No distractions or detours	Confidently navigated toward the classroom

10:28 am	S2	Indirect, zig-zag	Looking at the landmark all the time	Stopped and looked around	Stopped to talk with a friend	Took a long time, appeared confused but assured by the landmark
10:35 am	S3	Direct path	No interaction with landmark	Turned immediat at the junction.	None	Clearly familiar with the layout, knows exactly where to go

A variety of ethical matters were considered in conducting the methodology of this study, starting with an official email to the school's administration for permission to study the spatial structure of the buildings. The formal request included the study's aim, scope, and protocol. Specific requirements were considered during the visit, including the anonymity and privacy of the schools. In addition to ensuring children's protection and safety, no identifiable details or photographs of school staff or students will be taken or used. Lastly, all data will be collected responsibly and shared with the schools to ensure all regulations and conditions are met, fostering transparency in the research process.

4. Results

4.1. Buildings Layout Analysis

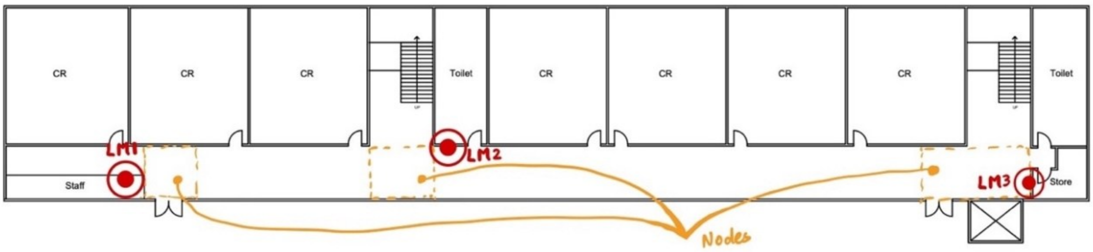

Figure 5. Floor plan of building 1 indicating the location of the landmarks (Source: Author).

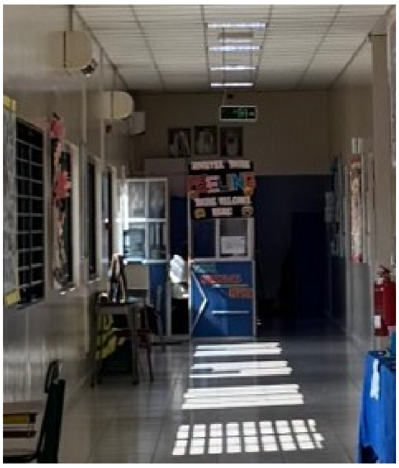

Figure 6. Landmark 1 of building 1 (LM1).

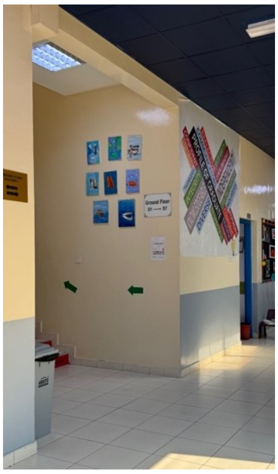

Figure 7. Landmark 2 of building 1 (LM2).

Figure 8. Landmark 3 of building 1 (LM3).

Figure 9 below shows the floor plan of Building 2 redrawn by the author. Focusing on the public corridor used by the children, the figure also indicates the location of nodes (orange) and landmarks (red). The nodes are identified as conjunctions or decision points. Contrasting visual elements at these points were then identified as landmarks. The visual elements are featured as color, shape, or texture changes. Consequently, four nodes have been identified in the building with four landmarks (LM1, LM2, LM3, and LM4) (Figure 10-13).

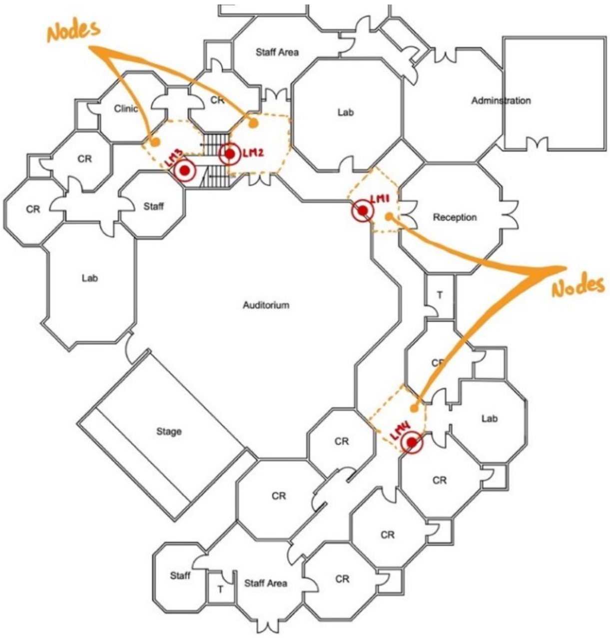

Figure 9. Floor plan of building 2 indicating the location of the landmarks (Source: Author).

Figure 10. Landmark 1 of building 2 (LM1).

Figure 11. Landmark 2 of building 2 (LM2).

Figure 12. Landmark 3 of building 2 (LM3).

Figure 13. Landmark 4 of building 2 (LM4).

While building 1 consists of three floors, only the ground floor is considered in this study. Figure 5 illustrates the floor plan of the ground floor redrawn by the author. Focusing on the public corridor used by the children, the figure also indicates the location of nodes (orange) and landmarks (red). The nodes are identified as conjunctions or decision points. Contrasting visual elements at these points were then identified as landmarks. The visual elements are featured as color, shape, or texture changes. Consequently, three nodes have been identified in the building with three landmarks (LM1, LM2, and LM3) (Figure 6-8).

4.2. Visual Graph Analysis

While using DepthmapX software and considering areas with the color red as an indication of a high visibility level and blue as a low visibility level, the visibility graph analysis of Building 1 analyzed using visual graph analysis is showing relatively high visual visibility in the main corridor, indicated by the colors orange and yellow (Figure 14). When compared to the landmarks' locations, all three landmarks (LM1, LM2, and LM3) are visible to users from any point of the building. In contrast, the overall visual connectivity of Building 2 is lower than that of Building 1 (Figure 15). However, LM1 in building 2 has a higher visibility compared to LM2, while LM3 has the lowest visibility between all landmarks. The level of visibility was then numerically measured with a 3-scale ranking where 1 indicates a low visibility level, and 3 indicates a high visibility level. Table 2 demonstrates landmarks' color code, visibility levels, and rank. Accordingly, B2 – LM1 was recorded to have the highest visibility rank, while B2 – LM4 had the lowest.

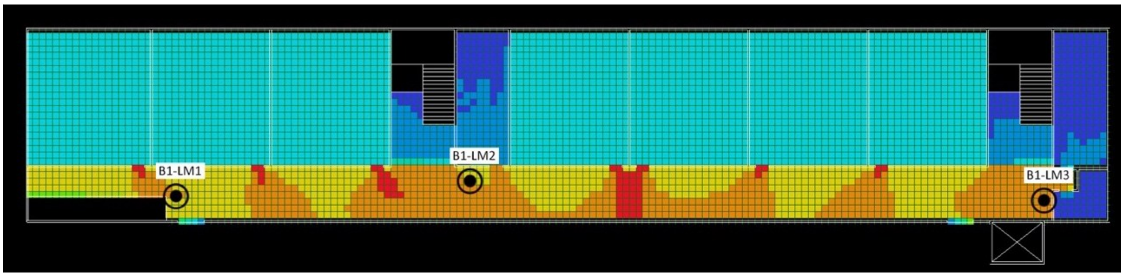

Figure 14. Visibility Graph Analysis of Building 1.

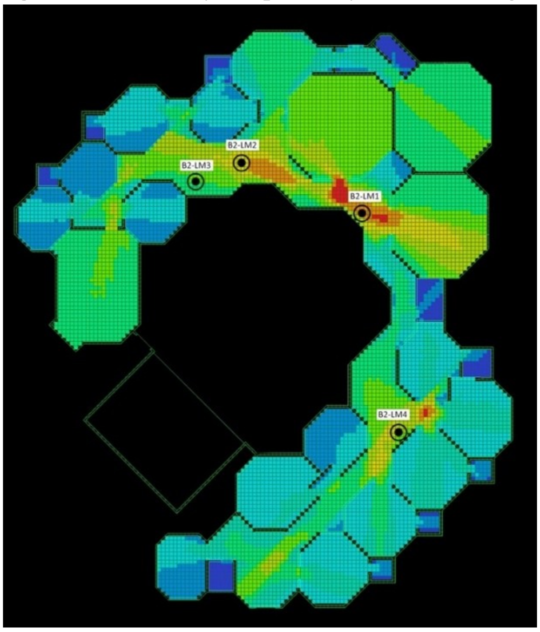

Figure 15. Visibility Graph Analysis of Building 2.

Table 2. The visibility level of landmarks in Buildings 1 and 2.

Landmark Code	**Color-Code**	**Level of Visibility**	**Visibility Rank** (1=Low, 2=Medium, 3=High)
B1 – LM1	Yellow/Orange	Medium	2
B1 – LM2	Yellow/Orange	Medium	2
B1 – LM3	Orange	Medium	2.5
B2 – LM1	Red/Orange	High	3
B2 – LM2	Yellow/Orange	Medium	2
B2 – LM3	Yellow/Green	Medium	1.5
B2 – LM4	Green	Low	1

4.3. Behavioral Analysis

Based on the activity log collected from all landmarks (example Table 1), the collected data was converted numerically to measure the landmark interaction count and navigation confusion count (Table 3). The interaction count refers to the number of participants interacted with a specific landmark. This include recognizing it during their wayfinding journey. For example, B1-LM1 was interacted with 6 times by the 10 participants. The navigation confusion count refers to the number of participants showed signs of confusion or uncertainty in the area near the landmark. This includes hesitation, taking wrong turns then coming back, or expressing doubt by looking at all possible decisions multiple times. For example, one instant of confusion occurred near LM1 in Building 1. The interaction and confusion difference are calculated by subtracting the landmark interaction count from the navigation confusion count. This value shows whether the landmark helped reduce confusion or if confusion outweighed interaction. For example, in B1-LM1, the interaction count is 6 while the confusion count is 1, which equals to the value of 1, while in B1-LM2 the value is -4. Accordingly, positive numbers indicate more interaction with the landmark than confusion, suggesting landmark effectiveness, while negative numbers indicate more confusion than interaction, suggesting landmark may be ineffective, misleading, or not visible. The interaction and confusion difference were then interpreted as confidence level (categorized as high, medium, and low) with each level assigned to a corresponding numerical value, where 3 equals to high confidence and 1 equal low confidence. For example, B2-LM1 has the highest interaction and confusion difference indicating a high navigational confidence.

Overall, Table 3 indicate that at B1-LM1, a moderate interaction count is paired with a moderate confusion count, suggesting that the lack of interaction with the landmark may affected the confidence in navigation. Landmarks may not be providing clear navigational cues. At B1-LM2 and B2-LM3, a lower interaction count is combined with high confusion and distraction, resulting in lower confidence in navigation. This result indicates that this landmark might be causing more confusion than aiding navigation. Landmarks B1-LM3, B2-LM2, and B2-LM4 show good interaction but with a moderate confusion count, suggesting that the landmarks are somehow useful but might need adjustment to enhance navigational confidence. In contrast, B2-LM1 shows a high interaction and low distraction count, resulting in high navigation confidence; this suggests the effectiveness of this landmark as a navigational aid. Generally, the level of landmark interaction is found to affect the navigational confidence within the two buildings.

Table 3. Landmarks' interaction and confusion frequency count for Buildings 1 and 2.

Frequency Count	**Landmark Interaction Count**	**Navigation Confusion Count**	**Interaction and confusion difference**	**Navigation Confidence Level** (High, Medium, Low)	**Navigation Confidence** (1=Low, 2=Medium, 3=High)
B1 – LM1	6	5	1	Medium	1.91
B1 – LM2	4	8	-4	Low	1
B1 – LM3	7	5	2	Medium	2.09
B2 – LM1	9	2	7	High	3
B2 – LM2	7	4	3	Medium	2.27
B2 – LM3	5	7	-2	Low	1.36
B2 – LM4	8	4	4	Medium	2.45

4. Discussion

Visibility graph analysis using Depthmap software illustrated medium visual visibility for landmarks in Building 1. However, the complexity of the spatial layout in Building 2 resulted in different levels of visibility for its landmarks. Although B2-LM1 scored a higher visibility level compared to all landmarks in building 1, B2-LM4 recorded lower visibility between all landmarks of both buildings. On the other hand, the study reveals that children's interaction with landmarks and confusion counts in buildings 1 and 2 affect their navigational confidence. B1-LM1 shows moderate interaction and confusion, while B1-LM2 and B2-LM3 show lower interaction and confusion. Landmarks B1-LM3, B2-LM2, and B2-LM4 show good interaction but moderate confusion, suggesting they might need alteration to enhance the navigational confidence.

To evaluate the impact of landmarks' visibility on navigational behavior, results from the visual graph and behavior analysis are combined and illustrated in Figure 16. Landmarks B1-LM1, B1-LM3, B2-LM1, B2-LM2, and B2-LM3 show a similar rating between landmark visibility and navigational confidence, suggesting a significant correlation between landmark visibility and navigational behavior among children. However, although B1-LM2 shows moderate visibility, the low rank of navigation confidence indicates that the landmark may lack key qualities needed to aid navigation, potentially due to factors such as its height, design, positioning, location, or overall scale. In contrast, a noticeable case can be found at B2-LM4, which recorded a low visibility rank paired with high navigational confidence. This implies that certain non-visual characteristics, such as strategic placement, intuitive form, or distinctive design features, may contribute significantly to its effectiveness as a navigational cue.

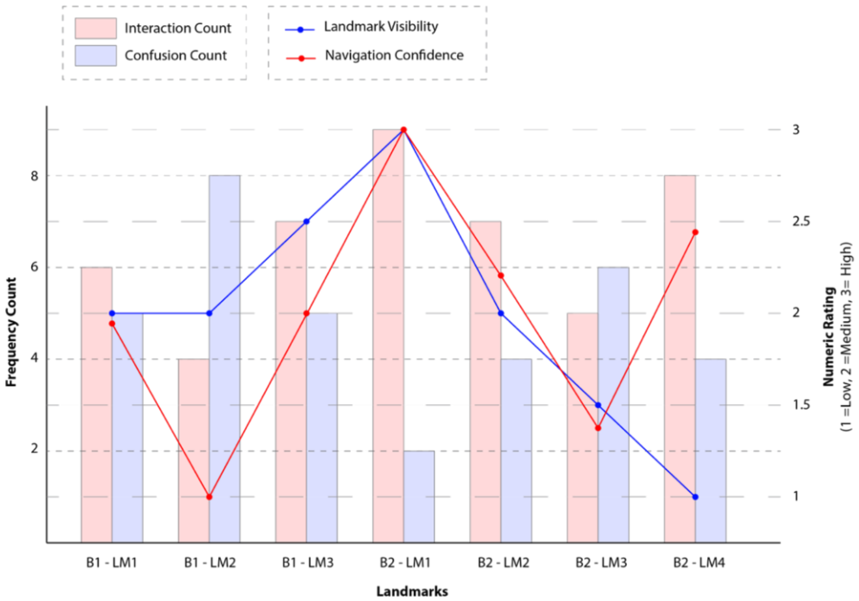

Figure 16. Impact of landmarks' visibility on wayfinding behavior chart.

Consequently, the study shows a significant impact of visibility on wayfinding behavior. Children in primary schools may find landmarks helpful during their navigational journey when they are nearby. Therefore, landmarks' effectiveness could be improved by increasing their visibility. However, landmarks don't necessarily need to be highly visible to be effective; while visible landmarks may attract attention, they might not always provide clear direction, leading to distraction or confusion. Other factors, such as placement, position, design, size, etc., may also influence their functionality. It is important to mention that familiarity is a crucial factor in navigational behavior; the activity log used during the observation indicated various children taking a direct path without looking at landmarks, suggesting that they depend on their familiarity during their journey rather than landmark reassurance. While landmark visibility doesn't consistently lead to high confidence, future studies could focus on the impact of these elements on wayfinding confidence among children. Thus, besides placing landmarks in high visibility areas, this study recommends designers and decision-makers refine highly visible landmarks considering their location, orientation, color, or more initiative positioning. The study then questions the impact of strategic placement over visibility on improving navigational clarity and children's wayfinding performance.

5. Conclusion

Wayfinding is the process of navigating a physical space by identifying and navigating through space; it involves complex cognitive processes and requires individuals to gather data from their surroundings. Many environmental elements can aid this navigational process; however, landmarks are seen as effective as they serve as stable reference points. The impact of landmarks on users' wayfinding experience is influenced by their intrinsic characteristics and perceptual and cognitive interpretations. Landmark effectiveness can vary according to user familiarity, cultural context, gender, and age, affecting how individuals identify and interpret navigational cues. While visual is one of three factors that make landmarks salient, through material, color, and shape, children naturally develop through their interactions with their environment; the physical elements significantly influence children's spatial perception and cognitive development. Consequently, landmarks' visibility became a crucial factor for navigational performance.

Therefore, this study explores the impact of visual landmarks' visibility on children's navigational behavior in Bahraini primary schools. By assessing the visibility of visual landmarks in Bahraini schools and evaluating children's navigational behavior, it aims to provide recommendations for school designers and decision-makers on incorporating effective landmarks in school environments. The study uses behavioral analysis through users' observation and spatial analysis through VGA across two school buildings in Bahrain. Visibility Graph Analysis (VGA) measures landmark visibility using a drawn and annotated map through DepthmapX software. Additionally, the study collects data on children's navigational behavior through observation, covert recording, and activity logs. The data is analyzed through descriptive frequency count to document movement patterns, landmark interactions, decision points, and distractions.

Accordingly, the study identified three visual landmarks in Building 1 (B1-LM1, B1-LM2, and B1-LM3) and four in Building 2 (B2-LM1, B2-LM2, B2-LM3, and B2-LM4). The Visual Graph Analysis in Building 1 highlighted high visual connectivity in the main corridor. In contrast, building 2 showed lower visual connectivity due to layout complexity. On the other hand, the behavior analysis revealed that children's interaction with landmarks and confusion counts in buildings 1 and 2 affect their navigational confidence. B1-LM1 shows moderate interaction and confusion, while B1-LM2 and B2-LM3 show lower interaction and confusion. Landmarks B1-LM3, B2-LM2, and B2-LM4 show good interaction but moderate confusion, suggesting they might need adjustment to enhance the navigational confidence.

Combining the spatial and behavioral results reveals that visibility significantly impacts wayfinding behavior in primary schools. Children may find landmarks helpful during their navigational journey and increasing their visibility could improve their effectiveness. However, landmarks don't have to be highly visible; they can attract attention but may not always provide clear direction, leading to distraction or confusion. Other factors like placement, position, design, and size influence their functionality. Familiarity is crucial in navigational behavior, as children often take direct paths without looking at landmarks. Therefore, the study proposes the following recommendations:

- Incorporate Distinctive Landmarks: Design visually striking landmarks using unique shapes, colors, or textures to be easily recognizable and memorable for children. Incorporate themes relevant to educational content or local culture, making them more relatable and engaging for students.
- Ensure Visibility and Accessibility: Position landmarks in naturally visible areas from various angles and distances while ensuring child-friendly height, avoiding overly tall structures that may be out of a child's field of vision.
- Consider other Factors: While landmarks' visibility is essential to ensure a positive experience, consider other external and internal factors like placement, location, design, size, and initiative positioning.

This study is limited by the sample size, where assessing two buildings in Bahrain may not represent all primary schools in Bahrain, limiting the generalizability of the findings. Additionally, relying on the researcher's interpretation may lead to inconsistencies in documenting children's behavior during the observation, leading to subjectivity of the results. Potential overlap of other influencer factors may affect the children's interaction with landmarks; this includes landmark placement, familiarity, and individual differences. Lastly, visual graph analysis considers horizontal visibility, which overlooks vertical visibility factors. In addition to expanding the sample size, future studies could focus on the impact of various factors on children's interaction with visual landmarks. Intervention studies (e.g., modifying landmark visibility) and technology integration (e.g., eye tracking) could also offer a comprehensive understanding of the impact of landmarks' visibility on children's navigational performance.

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Conflict of Interests

The Author(s) declare(s) that there is no conflict of interest.

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