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MEASURING DISCOVERABILITY IN BUILDINGS USING SPATIAL ANALYSIS AND OCCUPANT SURVEYS: A STUDY OF THE UWM UNION

by

Mahshid Jalalianhosseini

A Dissertation Submitted in

Partial Fulfillment of the

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Doctor of Philosophy

in Architecture

at

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August 2020

ABSTRACT

MEASURING DISCOVERABILITY IN BUILDINGS USING SPATIAL ANALYSIS AND OCCUPANT SURVEYS: A STUDY OF THE UWM UNION

by

Mahshid Jalalianhosseini

The University of Wisconsin – Milwaukee, 2020
Under the Supervision of Professor Brian Schermer

The architectural layout of a building influences the way people experience it. The more complex the layout, the overall size, the number of floors, and the more discrete spaces they contain, the harder it may be for people to discover the destinations and experiences that are available inside them. This is important because the more people are aware of what the building has to offer, the more likely they are to take advantage of these resources. This dissertation addresses the question: How do the layouts of buildings affect the potential of discoverability of places within them?

This study introduces and develops the concept of discoverability as a critical imperative for the design of complex buildings. Discovery of spaces within buildings may be influenced by a variety of factors, including their location, visibility, the particular need the setting serves, word-of-mouth or hearing from others, and marketing efforts through signs, posters, or emails.

Although each of these factors are important, this research focuses especially on the relationship between the visibility of a place and its discoverability. The study tries to develop a quantifiable definition for discoverability based on the measures derived from architectural analysis. The study evaluates three methods for measuring building configuration and visual accessibility: space syntax, visual graph analysis, and isovist analysis. Each approach offers benefits as well as shortcomings, the most important of which is their exclusive use of two-dimensional plan analysis. Thus, this study also introduces a new method for three-dimensional visual analysis using a Grasshopper script to produce a three-dimensional isovists.

The result of the visibility analysis of the building was compared to the results from an online survey of students that assessed how they experience the Union and their familiarity with different areas inside this building. Results from the survey showed that the visibility of a place is the most important factor involved in its discovery. Comparing survey results with visibility analysis results also revealed that among the different methods, axial line analysis, derived through space syntax could best correlate with students' responses about whether or not they discovered a place in the Union. The study also found that step depth, derived through visual graph analysis, is another important factor in the discoverability of places. The study provides an operational definition for discoverability based on these two concepts that can be used to measure how discoverable places are. The study also found that there was a relationship between the number of places that students had discovered in the Union and their perception of involvement opportunities in campus activities. This is an important finding which emphasized the importance of studying discoverability in complex settings like student union buildings.

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1. INTRODUCTION

Information is the key element by which people understand and explore the physical environments. People rely on information from many sources including other people, maps, and, especially, observing the environments in which they live, work, or visit. On the other hand, the physical layout of buildings can become quite complex, especially as they get larger and include more functions and destinations. This is the case in complex buildings like museums, large workplaces, student union buildings, etc., which offer many resources to the users of the buildings. The questions asked here are: How do people discover different areas within these complex buildings in the first place? What is the role of the physical environment of the building in facilitating this discovery? This research is thus concern with the potential of places to be discovered because the more people know about resources available to them, the more likely they are to utilize them and benefit from them.

In the context of environment and behavior studies there is a large body of literature on legibility and wayfinding in the built environment (Lynch, 1960; Weisman, 1981; Kaplan, 1982; O'Neil, 1991; Passini, 1992; Golledge, 1999). In this context, legibility refers to the environmental quality which allows people to understand the structure of an environment and develop a clear cognitive map of it. Wayfinding, which is a byproduct of legibility, refers to the process of determining and following a path between an origin and a destination (Golledge, 1999). Although the concepts of legibility and wayfinding are relevant to the questions raised earlier, they differ from discoverability.

Discoverability refers to the ease by which people are able to find destinations within a building. Destinations are discoverable if people know that they exist in a building. While wayfinding refers to getting from an origin to a destination, the focus of discoverability is on the potential for knowing what destinations exist in a building and the extent to which they are likely to be explored. Similar to wayfinding, legibility also has to do with the ability to understand spatial relationships between places within a building and developing a clear cognitive map. It relates to architectural layout, including destinations and circulation. Discoverability focuses on how individual places and destinations in a building come to be known over time. Discoverability, therefore, is related to the concept of architectural legibility wayfinding, yet there are important enough differences to warrant research to develop this new concept.

To further distinguish from the existing concepts, this study tries to develop a quantifiable definition to measure and predict the discoverability of individual places in a building. This definition is developed based on the analysis of the visual accessibility of places and analysis of the building layout.

It is also important to note here that although the focus of this research is to define discoverability based on architectural factors, there are other non-architectural factors that influence how places are discovered. These could include the function of a place and the need it serves, word-of-mouth and hearing from others, and marketing or the emails, signs, and posters that one sees before knowing that a place exists.

The current research focuses on a student union building as a case to study discoverability. The reason for this selection is that student union buildings play a prominent role in the way students experience campus life. They provide a range of services to help students succeed. They also provide welcoming settings for students to socialize, study, and become involved. Various involvement opportunities offered in union buildings contribute to the quality of student life. Therefore, students' awareness of these key resources not only affects their academic success and overall college experience but also can reduce student departure from the university by increasing students' engagement and providing students with opportunities to become involved in campus activities. College unions, like all buildings, are understood both spatially and visually. The way these buildings are experienced, therefore, has important implications for how people discover the different resources they have to offer.

The findings of this study will help shed light on designing more discoverable buildings. They therefore will be significant to a variety of audience groups. One key audience for this study is architects and space planners who design and program buildings. Another is people who research how buildings enhance users' experiences. This study will spark conversations about the importance of architectural layout and consequent visibility patterns in facilitating or hindering the discovery of spaces by building users. It also highlights the importance of programming spaces based on their different levels of discoverability provided by architectural layout. Another group of audience that this study may appeal to are design researchers interested in conducting quantitative analysis and graphical means for analyzing physical space in buildings. These analyses can be used in any stage of the design, from pre-design (for comparing different design scenarios) to post-occupancy (for evaluating spaces and comparing outcomes with empirical data). The methods of analysis introduced in this study can be used to study the social and physical worlds by coupling both quantitative and qualitative analysis. The current study can also be of interest to Union directors and higher education administrators who would like to maximize students' use of resources and involvement in the Union activities. This study can better help them understand the potential of spaces, evaluate how discoverable different places are and what are the areas that need to be further invested in to become more discoverable.

Purpose of the Study

This study evaluates how spatial qualities and configuration of architecture layouts can influence people's ability to discover places in complex buildings. By developing the concept of discoverability, including developing a quantifiable definition for it, the study calls attention to how architectural design can improve the way people find about the different spaces and experiences they offer.

The concept of discoverability applies to many types of complex buildings like museums, libraries, workplaces, etc. The focus on student union buildings is an excellent place type to study because they play an important role in students' experience of college campuses, including how they create access to different resources for academic success and provide opportunities for student engagement.

This study gathered data from students at the University of Wisconsin-Milwaukee through an online survey. The data collected was then compared to the visibility analysis of the layout of the building. The goal was to understand how well different measures of visibility within the UWM Student affect students' awareness of the existing Union building spaces. The main purpose of the study, therefore, is to use the result of visibility analysis and building measures derived from plan analysis to develop a quantifiable definition for discoverability.

Finally, it is important to mention that current visibility analysis methods mainly provide a planar representation of an environment and produce a two-dimensional analysis. Although helpful, they do not capture some spatial characteristics of a real-world environment. Therefore, in addition to developing the concept of discoverability, an important methodological contribution of this study was to develop a method for three-dimensional analysis of a building.

Research Questions

The main research question around which this study is framed is to define the concept of discoverability as a quality imperative to the design of complex buildings and understand its similarities and differences with wayfinding and legibility. These concepts are well-studied areas in the environment-behavior literature. Also, this study investigates the relationship between the discoverability of spaces and the configuration of the physical environment. The study is specifically trying to understand how the physical layout and visibility patterns in a student union building can influence students' ability to discover and find experiences and opportunities that the building has to offer. In this regard, the study is trying to find if more visible places are more discoverable. If that is the case, this study will help designers and planners better determine which places in a student union building need to be in the most discoverable locations? This will help with the programming of spaces to optimize visibility in relation to the function and importance of places. Therefore, the research questions for this study can be stated as:

1- What is discoverability and how does it relate to the existing concepts in architectural legibility and wayfinding?

2- Is there a relationship between discoverability of places with plan configuration and level of visibility?

3- How can we define a quantifiable definition for the discoverability of places based on the physical measures of the building?

To answer these questions this study looks at the relevant literature on ways to measure and analyze architectural spaces, as well as how people understand and find their way in the built environment. This study looks at the case of UWM student union building and tries to make the case for the important role of discoverability as a concept that better describes the critical importance of spatial and visual experience of building in helping people become aware of the resources that are available to them.

2. LITERATURE REVIEW

In this section, the existing literature pertaining to this research will be reviewed. The first and most important part of this section starts with the literature on how we understand our surrounding environment. It discusses perception, spatial cognition, and cognitive maps, legibility, and wayfinding in architectural spaces and develops a definition for discoverability based on the understanding of these concepts. The concept of discoverability will be developed with regards to visual access to different architectural spaces. Discoverability as the quality of places to be known by building users can be applied to a variety of building types including student union buildings, public libraries, museums, workplaces, and all other types of buildings that offer multiple resources to a variety of users.

The second part of this section then discusses methods of analyzing architectural space. This part introduces space syntax and visual graph analysis as methods for analyzing building floor plans and discusses the advantages and disadvantages of these methods. Discussion continues with a review of studies that have used these methods to analyze architectural space. The current study further identifies the need for a method for three-dimensional analysis of architectural space, which is currently missing from the literature in spatial analysis of buildings.

Finally, the last part of this section discusses the literature on higher education and the role of student union buildings in influencing students' experiences on college campuses. This part will also discuss how union buildings can help improve students experience and how the layout and physical organization of these buildings can affect critical outcomes for students socializing, learning, involvement, and success.

2.1. Wayfinding, Legibility, and Discoverability

In order to have a better understanding of discoverability in the built environment, we first need to study how human beings perceive and cognize the environment and how they store information regarding the physical setting in their minds through cognitive maps. This part will also review legibility and wayfinding in environments and studies how cognitive maps facilitate wayfinding behavior. It concludes by providing a definition for discoverability and how the physical environment can facilitate it.

2.1.4. Environmental Perception

Environmental perception is the process of obtaining information about one's surroundings (Lang, 1987). People depend on information from many sources especially, observation to collect information from their immediate environment (Kaplan, Kaplan and Ryan, 1998). Our perception of the physical environment is one of the most essential psychological processes which provides a foundation for all of our knowledge about the world around us. Perception helps us to direct our daily activities by providing information that is necessary to orient ourselves in the environment and helps us cope and adapt to novel environments and new settings (Holahan, 1982). Donald Appleyard (1970) studied urban perception and discussed the operational role of environmental perception in helping people orient themselves and travel efficiently in the environment. In his discussion, Appleyard points out that many features of urban environments are perceived because of their operational importance in efficient traveling.

There are some basic theories about how people perceive environments, among which the most important ones include Gestalt theory of perception, Ecological theory of perception, and Probabilistic theory of perception; the latter two of which are the most prevalent theories according to Holahan (1982) and Lang (1987). Ecological theory explains the process of environmental perception in terms of the nature of properties of environmental stimulation, while probabilistic theory emphasizes the active role of people in the perceptual processes (Holahan, 1982).

Based on the probabilistic theory, which is mostly developed by Egon Brunswik, the sensory information that reaches us from the environment is never correlated with the real environment and people usually come to a probabilistic estimate of the true situation. These probabilities are derived from the sampling of sensory cues from a great many environmental settings (Holahan, 1982).

On the other hand, through his ecological perception theory, Gibson (1979) argues that environmental perception is a product of the stimulation that reaches us from the environment. He discusses that we directly perceive the meaning that already exists in a patterned environment; that is unlike probabilistic theories, meaning is directly perceived in environmental stimulation and does not require an intervening process of reconstruction and interpretation on the part of the perceiver (Lang, 1987).

To detect meanings based on the ecological theory of perception, an observer does not have to attend to every variable contained in the optic array. Attention is selective. People attend to what they know about and what they are motivated to recognize. This depends on their prior experiences (Lang, 1987). Holahan (1982) also explains that in this process, learning plays an important role, since the perceiver learns to discriminate more important stimulus variables from the less important ones.

The invariant functional properties of objects that are discovered through active exploration of the environment are called affordances. Gibson (1979) defines the relationship between human and the environment through this concept and explains that the affordances of the environment are what it offers, provides or furnishes, either for good or ill. Identifying and analyzing affordances of an environment offers a functional methodological approach for analyzing people's perception of space inside buildings since human feelings and actions are limited by affordances of the environment (Lang, 1987). The basic processes involved in the interaction between people and the environment with regard to the concept of affordances are shown in Figure 1.

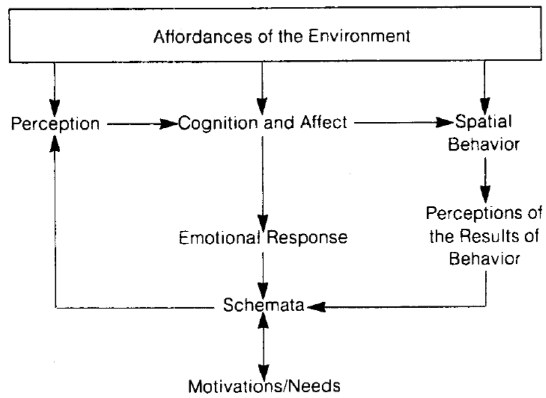


Figure 1: The fundamental processes of human behavior (Gibson, 1966 in Lang, 1987)

Space syntax[1] (Hillier and Hanson, 1984) researchers draw on Gibson's theory of ecological perception to argue the important role of configuration in people's spatial behavior, discussing that by understanding the syntactic measures of the environment we can understand behaviors like people's movement inside the space.

Although ecological and probabilistic theories are somewhat contradictory theories of environmental perception, however, there are a number of matters on which there is agreement among environmental perception theorists (Lang, 1987), including:

1- Perception is multimodal.
2- Movement plays a major part in environmental perception.
3- The assumption that perception is completely determined by the characteristics of the external stimuli is a dubious one.

[1] Space Syntax as a theory of analysis of environments will be introduced in the second part of this section

These are very important points in understanding the process of perception. We can conclude by highlighting the important role of plan configuration in guiding the flow of movement and therefore influencing perceptual processes, however, we should know that there is no guarantee for the role of characteristics of the environment and we can just describe the affordances of settings.

2.1.5. Environmental Cognition and Cognitive Maps

We have access to an enormous amount of information about environments that are not directly in front of us but stored in our heads (Kaplan, Kaplan and Ryan, 1998). Environmental cognition concerns the storage, organization, reconstruction, and recall of the images of environmental features that are not immediately present (Holahan, 1982). Environmental cognition theorists suggest that people store the significant physical characteristics of the environment in a mental representation (Kaplan and Kaplan, 1982). This psychological structure is referred to as the cognitive maps. People are dependent on the information stored in their cognitive map to guide them through the environments.

Although the cognitive map idea was first introduced by Tolman (1984), it was little appreciated until its reintroduction by Lynch's work (1960) in the image of the city (Kaplan and Kaplan, 1982; Holahan, 1982). Tolman (1948) found that rats in a maze-learning task acquired knowledge of the spatial relation between points of origin and destination rather than (or in addition to) a series of stimulus-response associations.

Cognitive maps are the internal representations of perceived environmental features or objects and the spatial relations among them (Golledge, 1999). Kaplan (1982) explains that objects or particular places are coded as representations in people's minds. They further note that the recorded representations do not arise as isolated experiences; rather they happen in relation to a variety of experiences, mainly those likely to follow it. With increasing experience, new landmarks form between old ones, yielding a cognitive map of increasing density (Kaplan and Kaplan, 1982). Therefore, representations of objects are the building blocks of cognitive maps and the continuity of these objects makes the difference between a collection of isolated representations and a coherent structure as in a cognitive map (Kaplan, 1973).

The way we use buildings and cities depends partially on how well their structures are remembered from past visits (Lang, 1987). Passini (1992) discusses the importance of spatial landmarks in the formation of a useable image of the spatial layout of the environment. Appleyard (1969) also discusses the importance of distinctiveness of the buildings and their attributes including visibility in making them good candidates for landmarks. Lynch (1960) believes that there are five elements that construct people's cognitive maps, including landmarks, nodes, paths, edges, and districts.

Kaplan and Kaplan (1982) demonstrate that Lynch's approach to cognitive maps and the five categories suggest discreteness rather than continuity. They introduce a network model of cognitive maps through a simple *point* and *connection* framework. They believe that Lynch's nodes and landmarks can fall under point category as they are both coded by representations and serve as a point in the cognitive map. They also suggest that districts and edges, at a higher level of abstraction, are recorded as points in people's cognitive maps, while paths can serve as the connection between points. Therefore, they believe that from a network point of view the notion of points (representations that correspond to places or objects) and connections (associations linking the points) is sufficient to form the building blocks of cognitive maps. The difference between Kaplans' and Lynch's model of the cognitive map is that Lynch speaks of these maps as five elements, all of which are equally important. Kaplans, on the other hand, consider cognitive maps as points and pathways, with points being the most salient elements in the cognitive map while pathways are less vivid.

Information in cognitive maps exists in some type of psychological space whose metricity may be unknown (Golledge, 1999). Therefore, cognitive maps can represent two distinct types of environmental information: (a) metrical relations that indicate the direction and distance between places, and (b) topological relations that show the ordering of places and their connections to each other (Kuipers, 1983 in O'Neil, 1991). A topological representation may be the minimum type of representation that a person can generate under constraints of time or processing overload and the minimum requirement for a successful route selection (O'Neil, 1991). Kaplan and Kaplan (1982) note that topological information is a natural byproduct of the learning process as one passes between places in the environment and that this same process allows us to assemble a useable representation of the environment from many small incomplete pieces or views. This acquisition of spatial knowledge presumably continues over long periods of time and supports sophisticated spatial behavior such as wayfinding and direction giving, as well as a feeling of place attachment. The long-dominant framework for understanding this process is based on Siegel and White (Siegel and White, 1975) study which supported the existence of different kinds of spatial representations in the development of spatial knowledge. Their study demonstrates that children's spatial representations pass from a first level, where they can represent only isolated *landmarks*, to a second phase where they can represent the *route* that connects these salient landmarks, to a third phase when they are able to make a more complex and general *survey* representation.

In brief, landmark knowledge is knowledge of distinctive objects or scenes stored in memory, while route knowledge is knowledge of travel paths connecting landmarks. Route knowledge consists of information about the order of landmarks and minimal information about the appropriate action to perform at "choice point" landmarks, such as turn right or continue forward. Such knowledge does not contain metric distance or directions, at least during the initial acquisition (Montello 1998). Survey knowledge is said to derive from the accumulation of route knowledge (Holscher, 2006) and is a representation of the metric spatial relationship between routes and landmarks.

In summary, vast amounts of the research on movement within the area of spatial cognition are based on an underlying assumption that the environment is represented in the form of cognitive maps and it is the cognitive maps that humans act upon when moving through their environment (Skorupka, 2010). By understanding people's cognitive maps of the environment, we can learn about salient places for people as well as other areas that are not as significant.

This will then help us evaluate the problem with those spaces that do not have character and meaning either because of the physical design or the programming of those spaces.

2.1.6. Legibility and Wayfinding

Golledge (1999) defines wayfinding as the process of determining and following a path or route between an origin and a destination. He demonstrates that wayfinding is a purposive, directed, and motivated activity. Passini (1992) also defines wayfinding as "to reach to a destination" for which one needs to depend on both cues from the environment and some knowledge of the setting or of similar settings that can contribute to wayfinding. Weisman (1981) relates wayfinding to the legibility of the building and defines legibility as the degree to which a building facilitates the ability of users to find their way within the setting. Lynch (1960) defines the legibility of an urban environment as the ease with which its features can be recognized into a clear and unified pattern. Kaplan (1982) identifies legibility as a quality involved in the prediction of preference of environments and defines legibility as the characteristic of an environment that enables people to explore without getting lost.

O'Neil (1991) includes both concepts of wayfinding and cognitive map in the definition of legibility and explains that architectural legibility is related to the degree to which the designed features of the environment aid people in creating an effective mental image, or cognitive map of the spatial relationships within a building and a subsequent ease of wayfinding within the environment.

Table 1: Summary of wayfinding and legibility definitions

Concept	Author	Definition
Wayfinding	Golledge (1999)	The process of determining and following a path or route between an origin and a destination.
	Passini (1992)	To reach a destination for which one needs to depend on both cues from the environment and some knowledge of the setting or similar settings.
Legibility	Lynch (1960)	The ease with which its features can be recognized into a clear and unified pattern.
	Weisman (1981)	The degree to which a building facilitates the ability of users to find their way within the setting.
	Kaplan (1982)	The characteristic of an environment that allows people to explore extensively without getting lost.
	O'Neil (1991)	The degree to which the designed features of the environment aid people in creating an effective cognitive map.

Based on these definitions, the legibility of architectural environments is an important design issue that influences the ease of wayfinding. Legibility can affect the degree of activity, while the illegibility of a setting may induce stress and result in lost time and efficiency (Evans, 1982; Passini, 1980; Weisman, 1987).

One of the first researchers to focus on legibility and wayfinding within buildings was Weisman (1981). He identified four general classes of environmental variables that shape wayfinding situations: visual access, the degree of architectural differentiation, the use of signs and room numbers, and floor plan configuration. Among these variables, layout complexity and the structure of the building as well as patterns of visual access seem to be the primary factor influencing wayfinding performance (Weisman, 1981; Rovine and Weisman, 1995; Holscher, 2006; Carlson et al., 2010). Familiarity with the building also has a substantial impact on wayfinding performance (Garling et al., 1983; O'Neill, 1992).

Passini (1992) also explains that the built environment facilitates wayfinding through signage, architecture, maps and information booths and, verbal instructions. Regarding the role of architecture and space, he believes there are three information structuring factors including spatial organization, spatial enclosure, and spatial correspondence that affect wayfinding within buildings. He defines spatial organization as the most important factor that establishes order among various inside spaces. The spatial enclosure as he defines permits the appreciation of architectural forms and is the second most important factor that facilitates image formation of buildings. He also explains that spatial correspondence affects image continuity of spaces within a setting and among settings and is the third important factor.

O'Neil's (1991) conceptual model of legibility suggests that the complexity of the topological plan configuration influences legibility. His model states that features of the physical environment influence the accuracy of the cognitive map, which subsequently affects wayfinding performance (Figure 2). The arrows between the variables in his model specify the predicted causal relationship.

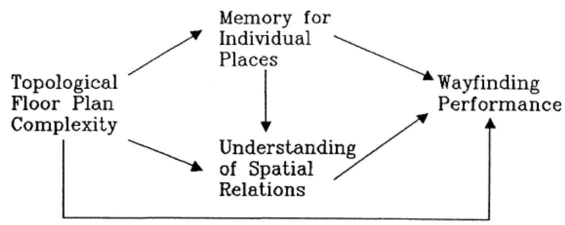


Figure 2: Structural model of legibility (Source: O'Neil, 1991)

Based on the literature mentioned here, the legibility of environments highly influences people's cognitive maps and consequently wayfinding performance. Therefore, it is important to have effective measures of legibility. To study legibility, researchers commonly use wayfinding performance, the accuracy of people's sketch maps of the built environment, or the correctness of recognizing pictures of the environment (Long and Baran, 2012). As will be introduced in the next section, space syntax is another method that has been widely utilized by researchers and can offer an objective, easier, and less time-consuming approach of measuring legibility compared to the existing methods.

2.1.7. Discoverability

The concept of discoverability in this study relates to the quality of space to be found and known by users of a building. The concept of discoverability is also a concern in user interface and product design, where it is thought that the usability of any piece of information directly relates to how discoverable it is. In other words: out of sight, out of mind. In this context, some of the benefits of designing for discoverability can include facilitating ease of use for the users, achieving more customer engagement, improvement in business revenue, and user satisfaction (Deodhar, 2019).

Because people have limited attention spans, web designers are always forced to choose which things are worthy of more attention to therefore prioritize them. The literature on human-computer interface discusses that the most important actions and options should always be visible and near at hand, while secondary actions and invisible structures should be easily discoverable at a second level by the user (Berkun, 2012, Del Turco, 2012).

As we saw earlier, people perceive and learn about environments as they move through them and accumulate their knowledge in a representation of the environment in their heads, called cognitive maps. The understanding of how characteristics of environment influence our cognition and cognitive maps helps in designing places that are easy to understand, explore, and discover. Discoverability can relate to the concepts of wayfinding and legibility that were discussed earlier, with some similarities as well as differences.

Based on the literature, wayfinding is mainly defined as the process of identifying and finding a path between an origin and a destination. A definition of discoverability as a quality that can describe awareness of resources in a building relates to wayfinding. The two concepts have similarities as they both rely on cognitive maps and the structure of the environment; however, the difference is in the way they refer to these maps. For a successful wayfinding task in an environment, a person needs to have clear representations (in Kaplan's words) or landmarks (in Lynch's word) as well as a clear structure among them. In other words, a person should know where different places are and know the topological relationships between them so he or she can find their way toward the destination. Discoverability on the other hand is mainly about destinations, *i.e.,* different places in the building. So, if a person knows about a specific place or where it is, the place is discoverable, even though the person does not necessarily know how to get there. In this sense, discoverability can be defined as the ability of users to know of and find different places in a building, and its focus is not on finding pathways but finding destinations. Knowing can occur through physical adjacency, visual access, or through hearing from peers and outreach.

Visual access plays an important role in discoverability. Although places that are easy to find from a wayfinding perspective are good examples of discoverable places, the opposite might not be true. An example of this could be a place that is located on the second floor of a building located near an atrium. This place might have a lower wayfinding score because of a lower physical accessibility, but because it is located by an atrium space where people can see it, it may discoverable because it is visually accessible.

Discoverability also relates to the concept of legibility, although there are slight differences. Legibility is mainly defined as the effectiveness of a building to facilitate movement and is often measured through wayfinding behavior. In this term, legibility is defined with a component of physical access, while discoverability as an extension of legibility is not concerned only with physical access but also the general knowledge of places in the building measured through visual access in this study. Furthermore, discoverability is defined in relation to individual places in the building whereas legibility mainly refers to the whole plan.

To further define the concept of discoverability, this research borrows two terms used by Kaplan (1982) as two qualities of environments: Legibility and Mystery. Although Kaplan uses these terms to study natural outdoor environments, it makes sense to apply them in building interiors as they are both concepts that identify qualities of the environment and can convey information from environments to the users.

As Kaplan defines it, legibility has to do with understanding of environments. Understanding is important as it relates to the desire people have to make sense of their world and comprehend what goes on around them. Understanding also provides a sense of security and when there is no or little legibility and people cannot understand an environment, they can become distressed.

As important as legibility and understanding of environments are, they are not enough. Kaplan discusses that people also want to explore and expand their horizons and find out what lies ahead. Here the quality of mystery becomes important in enabling people to explore and seek more information and look for new challenges. Mystery concerns information that suggests the potential for exploration, possibly because of the cues that imply there may be more to be seen. The desire to explore a place is greatly enhanced if there is some promise that one can find out more as one keeps going. Visual cues to places can provide hints of what there is and invite visitors to take a look, while blocked views lack any sense of mystery.

Therefore, the legibility of an environment helps people understand it, and mystery results in people exploring it. Applying the two qualities of legibility and mystery to the concept of discoverability, we can conclude that discoverability does not suggest that spaces should simply be large expanses. This might bore the users and suggest that nothing is going on and discourage them from exploration. On the other hand, a lack of permeability or obstructed views also do not encourage exploration as they suggest confusion and could lead to a concern about becoming lost. Visual cues can be provided through openings, transparency, and various other architectural strategies from spatially integrated places[2].

Finally, it is important to note that besides the important role of architecture, discoverability, or awareness of places may also not relate to building morphology. Sometimes functional importance makes places discoverable because people have to know about them, an example of this would be a transportation office in a union building, where students have to visit once a semester to activate their parking pass. Spaces in which students choose to enter voluntarily, such as a student involvement suite, however, might be more influenced by visual accessibility and permeability.

[2] The measure of integration will be discussed in the next chapter.

2.2. Spatial Analysis

The way the contents or elements in an environment are organized can make a significant difference in people's ability to pursue their basic needs of understanding and exploration (Kaplan, Kaplan and Ryan, 1998). Research on spatial cognition explains that the connections in the cognitive map are based on the topological relationship of places in the actual world (Kaplan and Kaplan, 1982). Therefore, if we can have a way to study the topological relationship of the physical environment we can get to an estimation of the structure of cognitive maps in people's minds. Literature suggests that space syntax can be used to study the configuration of environments and the development of spatial knowledge (Haq & Zimring, 2003). Penn (2001) explains that one possible explanation for such application of space syntax is that the way people understand their environment and decide on movement behaviors is somehow implicitly embedded in space syntax analysis.

This study uses space syntax analysis and visual Graph Analysis (VGA) as methods for analyzing architectural space. This part introduces and critiques both of these methods in terms of their advantages and disadvantage for analyzing spatial qualities of buildings. It also explains how different researchers have tried to overcome the limitations of the methods. These methods are discussed and evaluated here in an effort to understand their efficiency in describing the physical layout and consequently measurement of the quality of discoverability.

This part starts by introducing space syntax and visibility graph analysis, followed by the measures that these methods use to describe buildings physical layout. Then, studies that have applied these methods to analyze architectural spaces will be reviewed. Next, the advantages and disadvantages of each of these methods will be examined. The discussion concludes by identifying the gap in the literature on methods for 3D analysis of the built environment and reviews the few efforts that have been taken for this purpose.

2.2.4. Space Syntax

Space syntax is a set of techniques for representation, quantification, and interpretation of spatial configuration in buildings and settlements. Hillier (Hillier et al, 1987; Hillier & Hanson, 1984) explains that space syntax theory considers space not just as a passive backdrop for human activity, but as an environment that is intrinsically intertwined with everything we do. He defines configuration as the relationship among spaces in a complex, taking into account all spaces.

Space syntax proposes that cognitive space, defined as that space which supports our understanding of configurations more extensive than our current visual field, is not a metric space, but topological in nature (Penn, 2003), meaning that the way spaces are connected to each other might be more important than the actual distance between those locations. Therefore, space syntax analysis characterizes spatial systems based on the ways in which spaces are related to other spaces within a larger system, rather than through the more traditional characterization of metric distance (Wineman and Peponis, 2010).

Space syntax analysis starts by abstracting and representing the spatial relationships in the form of a graph and once the space system is represented, analyzes the relations. This initial graph that encodes the space and summarizes topological relationships is called a boundary graph. Every programmatic space in the building builds a node of the graph and the links in the graph indicate the accessibility between spaces (Hillier and Hanson, 1984).

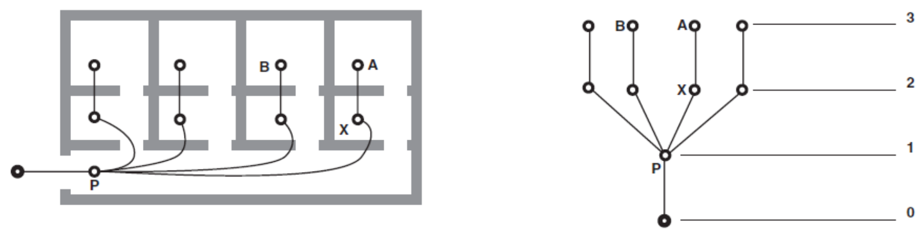


Figure 3: An example of mapping a schematic office setting onto a graph (Bafna, 2003)

With its analytical reduction of space to mere topological mathematical information, Space syntax facilitates the calculation of characteristic values that can be interpreted, for instance, as connectivity, centrality, or integration and thus directly compared (Wiener et al., 2006).

2.2.4.3. Space Syntax Method: Axial Line Analysis

Traditional space syntax proposed the technique of the axial map analysis of space. The axial lines (Figure 4) are a set of minimum number of longest straight lines needed to cover every space in the layout without crossing any physical objects. Axial lines would, therefore, construct the nodes in the produced graph of the space (Rashid et al., 2006).

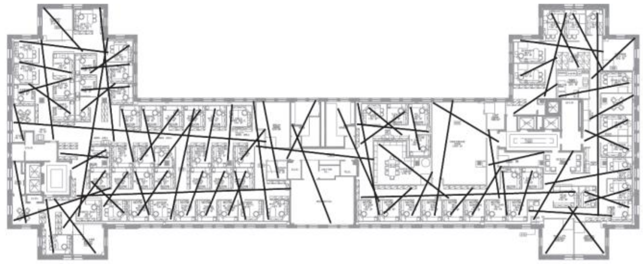


Figure 4: An office layout with its axial map (Rashid et al., 2006)

Axial line analysis is a technique that has been around since the very beginning of the development of space syntax theory. This method has some advantages and disadvantages that will be discussed later. Axial line analysis will be used in this study to analyze the UWM student union building. There is also another method of analyzing the space known as visibility graph analysis (VGA) that will be used in this study along with the method of axial line analysis. VGA draws from space syntax theory and the concept of isovist. Space syntax is already explained, and the next section describes isovist and VGA.

2.2.5. Isovist and Visibility Graph analysis (VGA)

2.2.5.3. Isovist

To describe VGA, we first need to understand the concept of isovist. Thiel (Thiel, 1961) was the first to point out the need for a tool that can be useful in representing the experience of form. Benedikt (1979) addressed this need for a simple, two-dimensional, and objective graphic means for the comprehensive mapping of environments through the concept of isovist (Figure 5). He defined isovist as the set of all points visible from a given vantage point in space and with respect to an environment. He explained that the shape and size of an isovist is liable to change with change in the position of the observer.

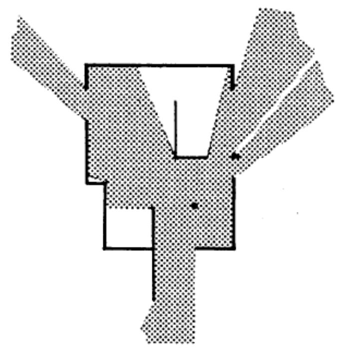


Figure 5: An example of an isovist, showing visible space (dotted area) from a single point (black dot) (Benedikt, 1979)

Benedikt suggested that the study of isovist is important in understanding behaviors and perceptions; however, he did not develop any specific relationship between isovist fields and behavioral attributes of people (Lu, 2009). In a later research, Wiener and his colleagues studied this relationship and found that isovist analysis captures behaviorally relevant properties of space and is a promising means for predicting experiential qualities of architecture and navigation behavior (Wiener et al., 2006). They found that isovist measure jaggedness (*i.e.,* polygon perimeter^2/area) was strongly negatively correlated with navigation performance and subjects' rating of clarity but found positive correlations between jaggedness and rated complexity.

2.2.5.4. Visibility Graph Analysis (VGA)

Turner and Penn (1999) found isovists to offer highly suggestive ways of interrogating spatial configuration; however, they argued that there are a few reasons for the limited application of isovists in architectural research. First, the difficulty entailed in the isovist production which results in a time-consuming procedure. Second, the geometric formulation of isovist measures means that they index purely local properties of space, and the visual relationship between the current location and the whole spatial environment is missed. To overcome these limitations, they developed Visibility Graph Analysis.

Similar to the method of axial line analysis that was described earlier, VGA is also a method for analyzing architectural space. To develop the Visibility Graph Analysis, Turner (2001) drew primarily on the space syntax theory of Hillier and Hanson (1984) and the concept of isovists (Benedikt, 1979). He suggested that through this analysis method, numerous local and global measures of spatial properties can be extracted, which are likely to relate to spatial perception and behavior, such as wayfinding, movement, and space use (Turner et al, 2001).

Turner's analysis encodes the inter-visibility of multiple observation points distributed regularly over the whole environment. This method starts with constructing a graph of mutually visible locations in which points in space serve as the nodes in the graph and direct connections between the nodes as the edge of the graph (Figure 6). This is similar to the method of axial line analysis, the difference, however, is that instead of the lines that form the nodes of the graph, in VGA every single point on the plan can be a node of the graph. The graph will then be analyzed using graph measures. Turner's 'Depthmap' software was developed to create the graph and conduct the analysis (Turner et al., 2001).

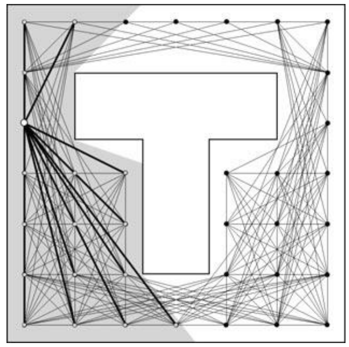


Figure 6: An example of a visibility graph, showing the pattern of connections for a simple configuration (Turner et al., 2001)

The latest version of the software, DepthmapX (Varoudis, 2012) is developed to produce visibility maps by taking the floor plan as input and dividing the plans into a grid of cells (Figure 7). It then calculates the number of cells that are visible from each stationary point and generates a map with color values correlating the range of visibility (blue for lower visibility to red for higher visibility values.)

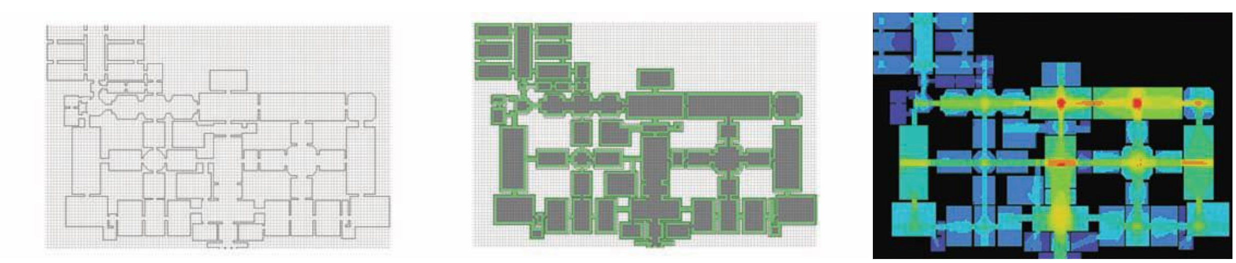


Figure 7: DepthmapX interface (Varoudis, 2014)

Turner et al (2001) explained that in order for the analysis to relate to human perception, the resolution of this grid must be fine enough to capture meaningful features of the environment in the human movement scale. He used a 0.5 and 1-meter (1.6 and 3.2 feet, respectively) grid in his analysis of two buildings.

2.2.6. Measures

The current study utilizes both methods of space syntax axial map and VGA to find which one can best relate to people's awareness of places and the concept of discoverability. Both of these methods generate similar quantitative measures to describe and analyze the physical space as will be introduced here. These measures include connectivity, integration, and step depth which have similar definitions in both axial map and VGA methods.

The connectivity value is the number of nodes (immediate neighbors in the graph) that are directly connected to a node (Figure 8). Connectivity captures the number of direct visual connections, which represents how many destinations can be seen or reached from a location or a line. In VGA, connectivity value can represent the openness of a space (a node). Connectivity does not say anything about the location of a node in the whole graph. Rather, it just reports the number of immediate connected neighbors and therefore is considered to be a local measure as it describes the relationship to the immediate surrounding places.

The integration value, on the other hand, is a more complicated measure and represents the degree of connectedness of each node to all other nodes in the graph. In other words, the integration value describes the average depth of a space to all other spaces in the system (Figure 9) and is a measure of topological accessibility. The higher the integration value, the easier it is to get to the node from all other nodes (Rashid et al. 2006). Integration is a global measure as it represents the location of a node with regard to all the other nodes in the graph.

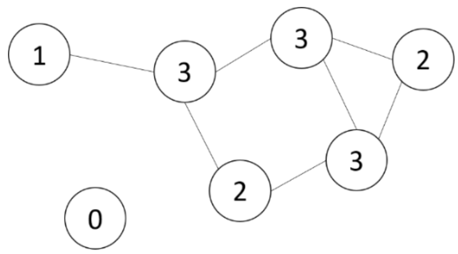


Figure 8: Connectivity

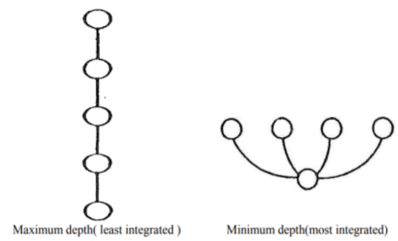


Figure 9: Integration

A well-integrated location (colored in red in Figure 10) is shallow, that is you do not have to turn often to get from that location to any other location in the system or vice versa. Conversely, a poor integrated location (colored in dark blue) is deep with respect to the other locations (Pinelo and Turner, 2010). It is also worth mentioning that each of the lines in the axial map analysis or cells in the VGA analysis has a numeric value associated with them and the color-coding is based on those values.

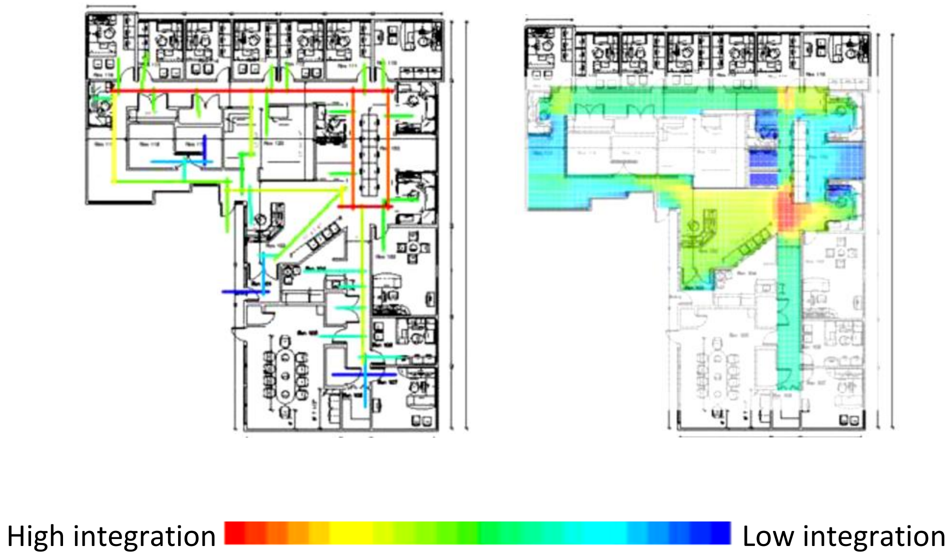


Figure 10: Axial integration (left) and VGA integration (right) of an office space (Deb, 2010)

One other measure that can be derived from both axial map and VGA map is step depth. Step depth illustrates the number of steps (changes of direction) it would take to get from the selected location to any other location in the graph. The selected location has step 0. All locations directly visible from selection or connected to it have step 1; all locations directly visible from those at step 1, have step 2, and so on throughout the graph (Pinelo and Turner, 2010) (Figure 11).

Figure 11: Step depth analysis (The arrow shows the selected location with step depth value of zero. Yellow color shows all areas with a step depth 1 value, green shows 2, light blue 3, and darker blues 4 and 5.

Table 2: A summary of measures

Measure	**Definition**	**Indicator of**
Connectivity	Number of nodes (spaces) that are directly connected to a node	The openness of a space and access to its adjacent spaces
Integration	Degree of the connectedness of each node to all other nodes in the graph	Average depth of a space to all other spaces; accessibility in the whole system
Step Depth	Number of steps (changes of direction) to get from the selected location(s) to other locations	Depth value for selected locations

2.1.4. Objective Evaluation

A disadvantage of the initial line of research on wayfinding is that floor plan complexity and configuration as well as visual access were defined informally and through subjective ratings (Holscher, 2006). An example of this is Weisman's (1981) assessment of the complexity of the physical environment which was based on a subjective assessment by judges.

One of the first efforts for overcoming the problem of the subjective evaluation was Peponis, Zimring, and Choi (1990) who used space syntax as an objective method of analysis of architectural space and suggested that there is a relationship between spatial cognition and space syntax. They used the measure 'integration' and showed that there is a relationship between the level of integration and the relative use of the space during the observed wayfinding task. They realized that highly integrated places within a building were more likely to lie along paths chosen by people during a search.

In another study, Kim and Penn (2004) investigated the effects of the spatial configuration of the local environment on residents' spatial cognitions of their built environment by examining the relationship between the spatial syntax of sketch maps that were drawn by residents and the spatial syntax of the environment. Analysis of the spatial characteristics of the area and the sketch maps using space-syntax methods showed that there was a strong correlation between residents' sketch maps and the spatial configuration of the area.

Haq and Zimring (2003) explain that because space syntax deals primarily with topological information, it is an important tool to test wayfinding problems. In their study, they focused on the development aspect of topological knowledge of building layouts in a hospital setting and found that during initial exploration, people rely more on local topological qualities, such as how many additional nodal decision points could be seen from a given node. As they got to know the setting better, their wayfinding behavior was better predicted by more global qualities such as the space syntax integration of a node. Haq and Zimring (2003) suggested that people rapidly move from a local to a more global topological understanding as they learn a setting.

Wineman and Peponis (2010) researched the role of spatial layout in shaping the ways in which visitors explore and engage in museum spaces. Through space syntax analysis of two museum settings and behavioral observation of visitors, they found that behavioral patterns are systematically linked to spatial characteristics of access and visibility, and patterns of visibility and accessibility are more powerful predictors of movement than metric measures. They found that the more accessible an exhibit element is from all other exhibit elements, the more likely it is to be visited.

Brosamle et al. (2007) studied the relationship between space syntax measures and wayfinding behavior of individuals in a hospital setting. They found that the majority of the usability hotspots in the building could be linked to measures of step depth, connectivity, and integration as calculated through space syntax.

These studies all used space syntax analysis as an objective method to evaluate architectural spaces and were able to draw a correlation between the description of space as derived from space syntax analysis and behavioral data. Table 3 summarizes the empirical studies reviewed so far and their findings on the relationship between the configuration of environment and legibility and wayfinding ability in those environments.

Table 3: Empirical studies on legibility and wayfinding

Author	Plan Measurement (Analytical Description Method)	Finding
Peponis, Zimring, and Choi (1990)	Space Syntax axial map (Lines of sight)	The integration value of axial lines predicts space use during a wayfinding task. The higher the integration value, the more people rely on those paths to find their way.
Kim and Penn (2004)	Space Syntax axial map (Lines of sight)	Spatial syntax of configuration in real environments and spatial syntax of cognitive maps in spatial cognition are closely related.
Haq and Zimring (2003)	Space Syntax axial map (Lines of sight)	People rely more on local topological qualities (connectivity) during the early stages, while their wayfinding behavior will be better predicted by global measures like integration as they get to know the setting better.
Wineman and Peponis (2010)	Space Syntax axial map (Lines of sight and access)	Visibility and accessibility are linked to behavioral patterns.
Brosamle et al. (2007)	VGA and Space Syntax axial maps	Individuals use of places can be predicted by space syntax measures.

2.2.7. Advantages and Disadvantages of the Methods

2.2.7.3. Advantages of Axial Line Analysis

In its initial form, axial line analysis focused mainly on patterns of pedestrian movement in cities, but in recent years its application extended to support experimentation and inform architectural and urban design research as well. Haq and Zimring (2003) explain that because space syntax deals primarily with topological information, it is a potentially important tool to test wayfinding problems, even before complex buildings are constructed.

Axial line analysis is a promising way of revealing underlying morphological structure as it utilizes powerful resources of graph theory and matrix algebra by transforming building plans into graphs (Osman and Suliman, 1994). Monetllo (2007) explains that this analysis method provides a rich and diverse set of quantitative indices for characterizing places in many ways that are potentially relevant to a variety of psychological responses, including choosing routes while locomoting, orientation and disorientation, spatial knowledge acquisition, perceived spaciousness, privacy, and social interaction, stress and fear, and aesthetic judgments.

Another advantage of the axial line analysis method is its application for correlation studies. Since each programmatic space usually receives a unique number in the method (due to each space being represented by a single line), it is easy to use this method for correlational purposes including correlation of any real-world behavioral patterns with space syntax measures[3].

2.2.7.4. Shortcomings of Axial Lines

Although many studies have proven the value of analyzing the physical environment using axial line analysis method, there are also debates on a number of potential shortcomings of axial lines analysis that is discussed below:

2.2.7.4.1. Binary Coding

One of the shortcomings of axial line analysis is the binary coding, 1 for the direct connection between a pair of spaces and 0 for the absence of direct connectivity (Osman and Suliman,

[3] As will be discussed later, VGA reports values for a large number of points on the layout, therefore one might need to calculate an average of all values of a single space to compare with behavioral data.

1994; Montello, 2007; Ratti, 2004). This binary coding can leave out various types of connectivity which in reality can exist between two spaces. Figures 12 and 13 illustrate different types of connectivity that might exist between two spaces, which are treated equally when translated into a graph. Various connections through doors, windows, and screens and whether to leave or keep those kinds of connections are also obscured in this method.

In response to these kinds of critiques, Penn (2003) notes that cognitive maps are comprised of topological relationships, meaning that the spatial organization and relationship between spaces are more important than the actual distance between or size of those spaces. This justifies why space syntax does not differentiate between variations presented in Figure 13. However, the oversimplification of the space into mere topological relationships remains one of the main critiques of this method.

It is also important to mention that axial line analysis differentiates between physical accessibility and visual accessibility and suggests that researchers can choose to generate the lines based on one of these two approaches. Therefore, for example in the case where two rooms are connected only through a window, researchers can connect the two if they are focusing on visibility or not connect the two if the focus is on physical accessibility.

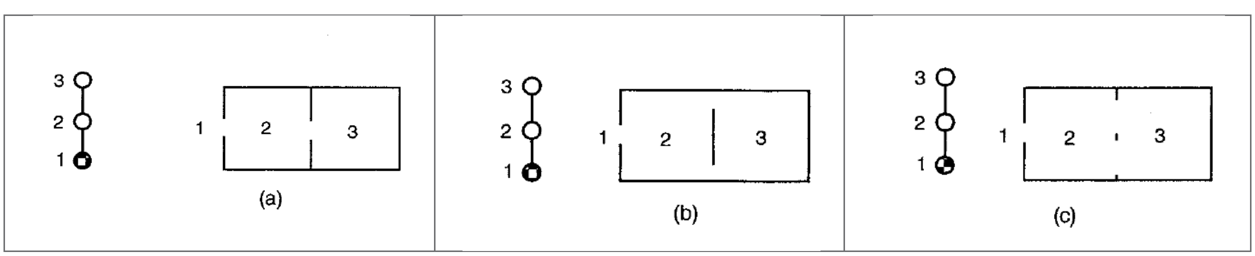


Figure 12: Different types of connectivity and their corresponding relationship into a graph (Osman and Suliman, 1994)

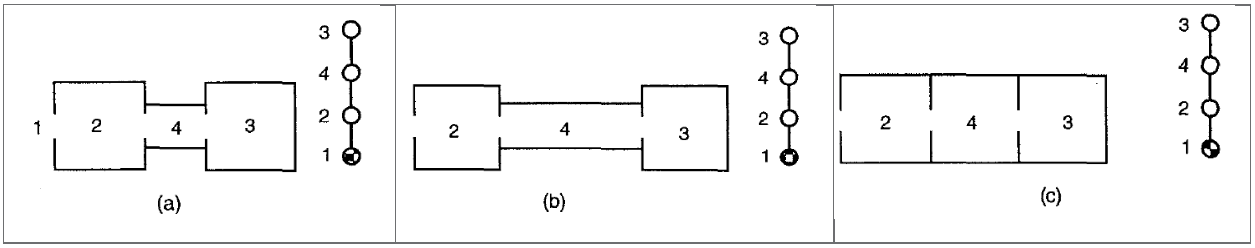


Figure 13: Different types of connectivity and their corresponding relationship into a graph (Osman and Suliman, 1994)

2.2.7.4.2. The Problem of Meaning

Another shortcoming of using space syntax axial line analysis is in its need for a complementary approach in understanding the meaning of spaces (Netto, 2015). Lawrence (1990) notes that the mere act of transforming the two-dimensional representation of a building to a graph does not yield information about psychological, social, cultural, or temporal issues. Space syntax measures used in the quantitative description of spaces may represent the affordances (Gibson, 1979) of the environment, but do not dictate the meaning and uses. Therefore, the measurement itself is not particularly meaningful unless supplemental approaches including social science methods are used to collect data about the socio-spatial context.

2.2.7.4.3. The Third Dimension

The traditional method of axial map analysis generally focuses on the two-dimensional floor plan and analysis. This is helpful for one-story buildings, however, in the case of multistory buildings, analysis is conducted on each individual floor and falls short in studying the building as a whole. This is important as vertical relationships in multi-level structures can affect orientation and spatial learning in buildings (Montello 2007; Ratti, 2004).

To overcome this shortcoming, some studies have tried to apply the method to three-dimensional spaces by manually adding a link between floors. In order to do so, different floor levels were connected manually by circulation spaces like stair areas and elevators using an additional axial line (Holscher et al, 2012; Wineman et al, 2009; Chang and Penn, 1998). Figure 14 shows an example of such a manual connection between floors.

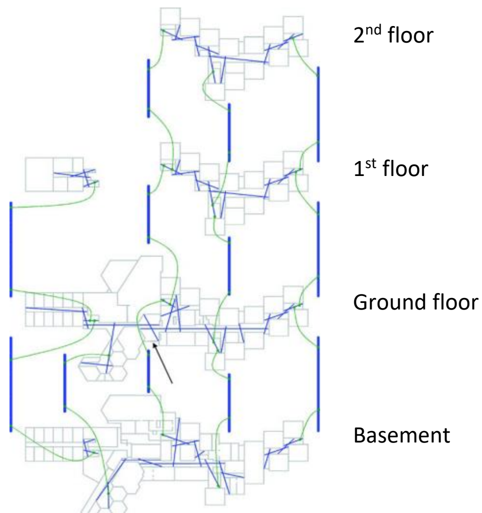


Figure 14: Axial lines in the navigation space (corridors and stairs). Manual links are shown with green lines, axes connecting floors are drawn in bold blue color (Holscher et al., 2012)

2.2.7.4.4. Subjective Drawing of Lines

Traditionally an axial line map is expected to be a fewest and longest line map (Hillier and Hanson, 1984), however, some uncertainty appears in the process of producing these maps. Some authors point out that this uncertainty could change the topology of the axial map and therefore cascade onto space syntax results (Ratti, 2004; Batty, 2001; Jiang and Claramunt, 2002; Desyllas & Duxbury, 2001). Desyllas and Duxbury (2001) also believe that this interpretative role for the person drawing the map raises the problem of reliability.

In response to this critique, Hillier and Penn (2004) introduced a set of criteria that they believe should be met while drawing axial maps and believe that carefully following those criteria will result in one correct line graph, even if minor variations are possible in axial maps. Despite such algorithms and criteria, there is still not an automated way to create a uniquely defined axial map for a given space and sometimes the researcher has to manually generate the axial line map, based on his or her judgment (Holscher, et al., 2012).

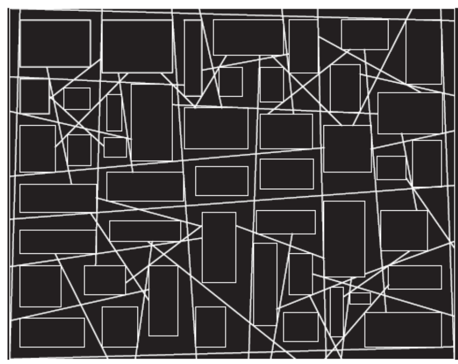


Figure 15: Axial line of a hypothetical layout. Hillier and Penn argue that using defined algorithms researchers can come up with a unique least-line axial map for different settings (Hillier and Penn 2004)

2.2.7.5. Advantages of VGA

The method of visibility graph analysis (VGA) has a lower degree of space abstraction in comparison to the axial representation, as VGA provides a more fine-grained representation of architectural space. This method is more detailed than axial lines in that it describes visual information conveyed to observers from any location (Natapov and Kuliga, 2015). As described in the disadvantages of axial maps, each line in the axial map is represented by a node in the graph, and so only a single value will be generated for all points along the whole length of the line. However, as isovists can be drawn at any location in space, a graph of lines-of-sight connections may be constructed easily, at any required degree of spatial resolution, by using the visual relationships between isovists (Turner et al, 2001).

The other privilege of VGA compared to traditional axial lines is that all axial lines need to be drawn by the researcher and therefore there is a level of subjectivity involved in that approach, whereas in VGA, the plan is divided into grid cells through an automated approach. This automated technique generates a regular grid of points within the entire study area and resolves the issue of reliability that exists with the axial map method (Desyllas and Duxbury (2001). Finally, some studies found a significantly higher correlation between pedestrian movement and the result of VGA analysis as opposed to axial graph analysis results (Turner and Penn, 1999; Desyllas and Duxbury, 2001).

2.2.7.6. Shortcomings of VGA

2.2.7.6.1. Subjective Drawing of Barriers

Subjectivity in VGA arises when deciding what area to include in the analysis. Looking at the studies that have applied VGA, some only consider the circulation paths and public spaces when analyzing building layouts, and do not include enclosed office rooms in the analysis (Holscher, 2012). This is especially the case when dealing with larger buildings. However, some other studies include the whole layout in their VGA analysis (Koch et al, 2012).

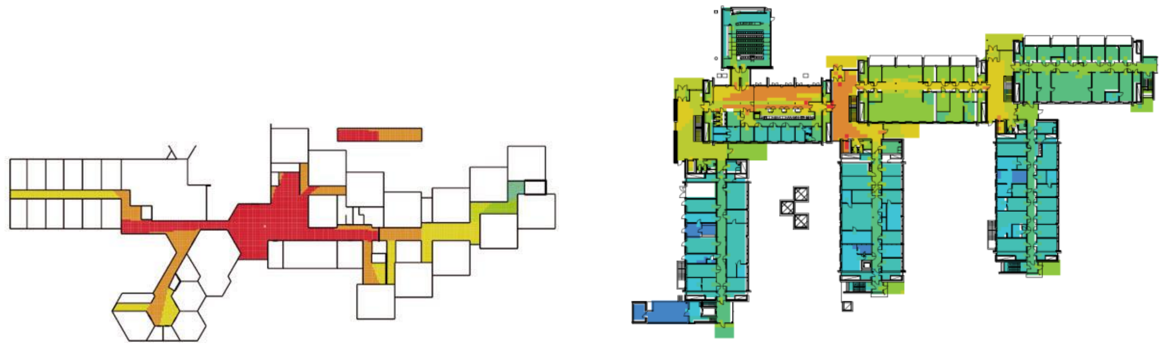


Figure 16: Including circulation path into analysis of a convention center (left) (Holscher et al, 2012) or the whole layout of an academic building (right) (Koch et al, 2012)

Space Syntax handbook suggests that at the most basic level, researchers may want to open doors within their plan to allow vision to pass through them. However, it leaves the decision to the researchers.

2.2.7.6.2. Transparent surfaces and half-height walls

The method of visibility graph analysis developed by Turner (2001) is restricted to analyzing spaces that only include fully obstructive walls or simple openings (Varoudis and Penn, 2015; Dalton & Dalton, 2009). Therefore, in practice, researchers in most cases have to remove some elements from the input drawings or extend and block other elements before performing the analysis. This results in a subjective judgment by the researcher for example as to whether a tinted glass will be a solid wall or a transparent opening. Although recent research has developed a method to overcome this issue (Varoudis, 2014; Varoudis and Penn, 2015), it is not yet available for public use.

This new method (Varoudis, 2014; Varoudis and Penn, 2015), called Augmented Visibility Graph Analysis (AVGA) allows complex origin-destination distinctions to be made. The following test scenario compares traditional VGA and the proposed AVGA to show how transparent materials (marked in dark brown in the Figure 17 left) can influence the measure of connectivity and how AVGA is capable of showing that in the analysis.

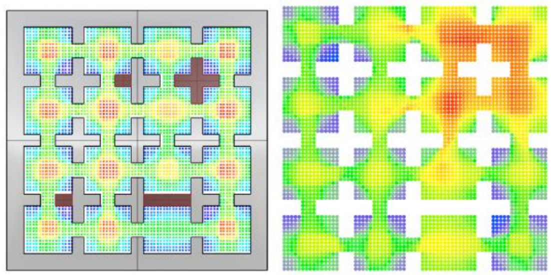


Figure 17: Comparing connectivity in a test layout in a traditional VGA (left) and AVGA (right) (Varoudis and Penn, 2015)

2.1.4.3. Vertical Connections Among floors

Even though VGA can describe complex spatial relationships, it is limited by the two-dimensional planar nature of this analysis. This is a similar disadvantage to the axial line analysis method which falls short in paying attention to vertical connections.

To overcome this problem some studies have manually added connections between floors to analyze the building as a whole (Turner et al, 2001; Holscher et al, 2012). In their study of a multilevel building, Holscher et al (2012) considered vertical interconnections in the staircases and modeled vertical connections manually. Visibility graph nodes in the floor plan were then manually connected with those in the widget representing the staircase (Figure 18 and 19).

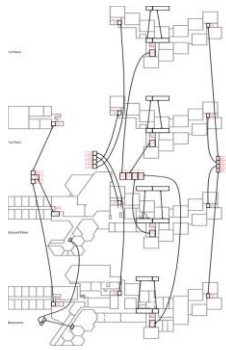


Figure 18: Manually generated connections and areas of vertical interconnection between floors for VGA (Holscher, et al., 2012)

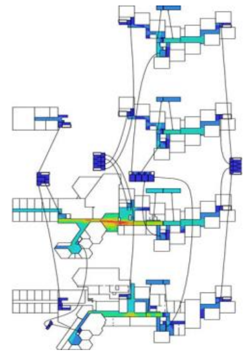
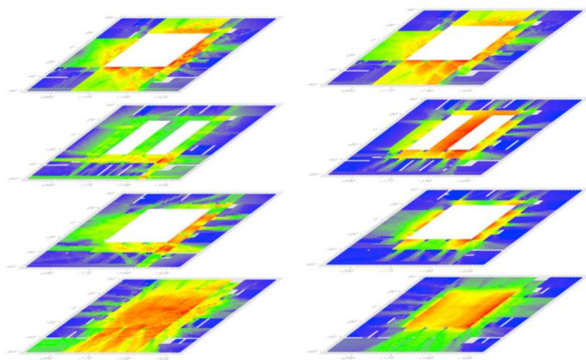


Figure 19: VGA of the navigation space in terms of connectivity (Holscher, et al., 2012)

2.1.4.4. The Third Dimension: Problem of Height

Three-dimensional visibility is an important issue, as people are often attracted to three-dimensional spaces for spatial orientation. These prominent spaces not only can impact peoples' wayfinding but also are key areas for community life. However, VGA falls short in dealing with the change of height inside the same floor and situations like atrium spaces in buildings (Koch, 2010; Varoudis and Psarra, 2014). Similar to the problem of transparent surfaces, there is a recent development to deal with the problem of 3D VGA, but it is not yet available for public use. In this new 3D VGA method, connections (edges in the graph) are made among all spatial points but values are reported for only occupiable points on the floor plan (Varoudis, 2014; Varoudis and Psarra, 2014). Figure 20 compares a 2D and 3D VGA and shows how a 3D VGA reveals the impact of an atrium's void on the distribution of visual connections along the vertical direction.



2D connectivity 3D connectivity

Figure 20: Comparison between 2D and 3D VGA connectivity (Varoudis and Psarra, 2014)

In summary, the questions underlying space syntax are very interesting ones and deal with a long-lasting dilemma amongst architects and urban planners to find the impact of built form on social life (Ratti, 2004; Turner, 2003). As seen here, these methods have delivered interesting results on many different functional aspects of the built environment and have also allowed to study the link between configuration, movement, perception, and use patterns.

Reviewing the advantages and shortcomings of the axial map and VGA analysis methods helps us better understand their value for investigating the configurations of student union buildings (Table 4). Axial line Analysis and VGA allow the quantification of layouts so that the environment itself can produce independent variables. This study aims to use this data as a set of predictor variables to compare with students' awareness of places in a student union building.

Gieryn (2000) believes that although space syntax can assist researchers with the study of spatial configuration, it detaches places from their material form and cultural interpretation and analyzes the physical space of it. Therefore, this study applies the analysis methods in combination with an online survey questionnaire to understand these accumulated meanings in spaces and compare them to the results of the analysis of the environment.

Table 4: Summary of advantages and disadvantages of space syntax axial map and VGA

	Advantages	Disadvantages
Space syntax axial map	• Quantitative description of the environment • Correlation with pedestrian patterns of movement • Simplifying building plans into graphs • Easy correlation with other measures due to the generation of a unique value for a whole space	• Binary coding: spaces are either connected or disconnected and there is no middle ground to represent various relationships between spaces. • The problem of meaning: space syntax can simply describe the geometry and topology of space, but environments are comprised of social as well as organizational aspects in addition to physical settings. • Vertical connections: traditional axial map analysis has been developed for 2D plan analysis and to study multistory buildings as a whole, requires manual connection between floors. • The problem of reliability and subjective drawing of axial lines
VGA	• Quantitative description of the environment with a more fine-grained representation of architectural space compared to axial line analysis • Higher correlation with pedestrian flow • An automated and objective process for generating more reliable maps.	• Vertical connections: similar to axial maps, VGA is limited to two-dimensional analysis and it is even harder to generate a manual connection between floors in this method • Problem of height: VGA provides less abstraction of space, yet it falls short in representing vertical characteristics of atrium spaces and areas in the building with staggered floor and ceiling heights

	• More application for architectural spaces compared to the axial line analysis method	• Subjective decision on identification of barriers and areas to include in the analysis • Transparent surfaces and half-height walls

2.1.5. 3D Isovist & View Analysis

As came up in the shortcomings of both methods of axial line and VGA, three-dimensional analysis is an under-studied area of research in spatial analysis with a few studies in recent years that have focused on this issue. This section reviews these studies and how they have generated and represented three-dimensional isovists in the study of the built environment.

One of the initial efforts to generate a 3D isovist was Derix who generated a polyhedral volume enclosing all visible points from a single location (Figure 21) (Derix et al., 2007). His approach was mainly focused on the representation of a 3D isovist with no further analysis of properties of the 3D isovist or how that could have behavioral implications.

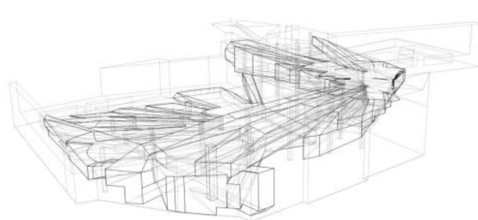


Figure 21: 3D isovist by Derix

Andrew Heumann (2011) used Grasshopper in Rhino to generate a similar concept and calculated an approximation of the visible space inside a given volume from a specific viewpoint. Although useful, similar to Derix, his method was simply a visual representation of isovist without the ability to measure the volume of visible space (Figure 22).

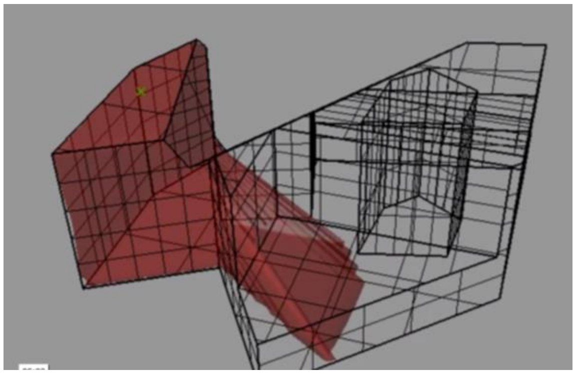


Figure 22: 3D isovist by Heumann

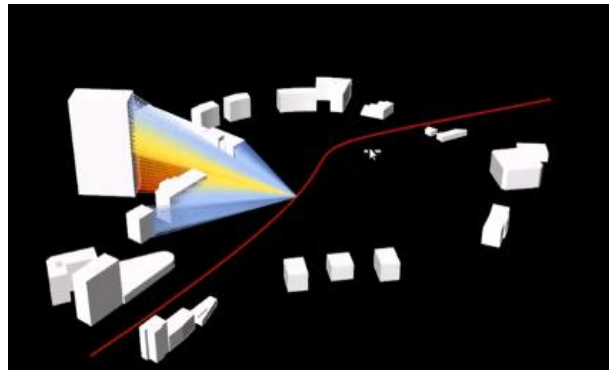


Figure 23: 3D isovist by Vescio

Mirko Vescio (2015) also provided an approximate calculation of a 3D visible space (Figure 23). This is again a visualization of the 3D isovist without measuring capability and it is represented based on lines of sights and not the volume of visible space. He used this approach for simulating visibility along a path in a hypothetical outdoor environment.

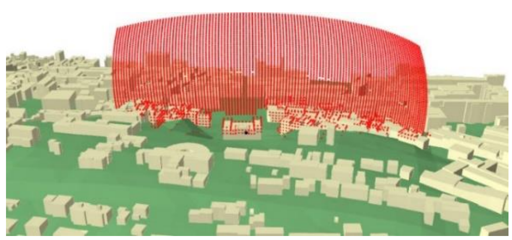


Figure 24: 3D isovist by Wassim Suleiman

In another effort, Wassim Suleiman (2012) developed a method for 3D urban visibility analysis with vector GIS Data. His focus was on the representation of visible points from a viewpoint in an urban setting (Figure 24), however, similar to the previous models, this approach is also mainly centered around visual representation.

Ratti and Morello (2009) used MATLAB to develop a method for calculation of 3D isovists in urban open spaces and were ultimately interested to find the visibility measures of building façade. In order to do so, they used the lines of sight to determine visible voxels from a single location and created a 3D matrix. To simplify the representations, they suggested to cut 2D sections through the isovist matrix and show how visible individual voxels are from a set of vantage points on street level by using a color scale (Figure 25).

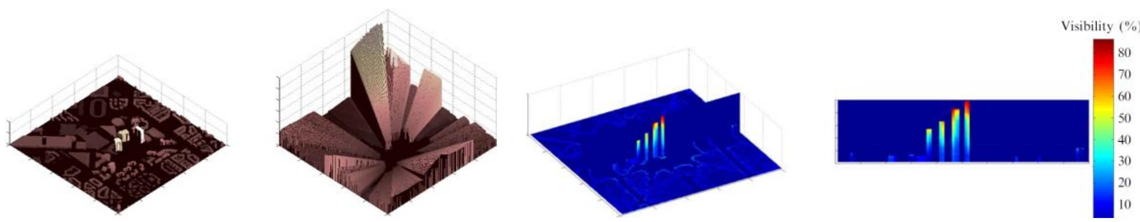


Figure 25: The section of the voxel space shows different levels of visibility of the facades of buildings. Red shows the most visible surfaces from all vantage points at street level

Dalton and Dalton (2015) study was not focused on the generation of a 3D isovist but the problem of representation of 3D isovists. They introduced three types of 2D representations of 3D isovist as: 'Contour Isovist'[4], 'Tri-planar Isovist'[5], and 'Circumvoluted Isovist'[6] (Figure 26). After surveying 20 experts who were familiar with the use of isovist in research, they realized

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[4] Contour isovist is defined as a series of corresponding isovists, all generated from the same x,y location in space, but calculated at differing heights. The different heights are then collapsed into a single, 2D representation, similar to a contour map. In this representation method, a thick/bold solid line indicates the conventional 'eye-height' isovist. Those contours below eye-height are drawn as thin solid lines and those contours above eye-height are shown as thin dotted lines.

[5] A 'Tri-planar Isovist' consists of one traditional isovist (generated in the horizontal place) shown in conjunction with two additional isovists constructed in the vertical place. All three isovists are generated at eye-height, from the same point in space, but in three different planes.

[6] A circumvoluted isovists represents the lines of 'unpeeling' a visible volume of space, starting at the top and gradually spiraling down.

that the ‘Contour Isovist’ and the ‘Tri-planar Isovist’ are easier to understand and most preferred by professionals.

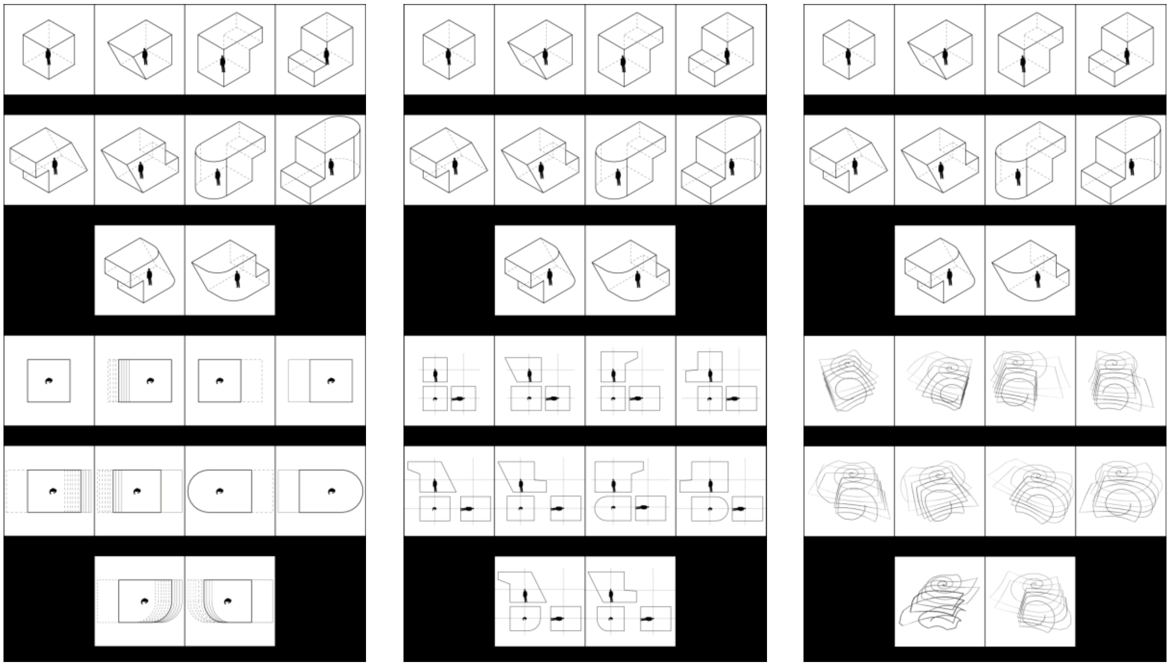


Figure 26: Three types of 2D representations of 3D isovist for 10 simple volumetric spaces (left: examples of contour isovists, middle: examples of tri-planar isovists, right: examples of circumvoluted isovists)

In the most recent research on generating 3D isovist, Díaz-Vilariño and his colleagues (Díaz-Vilariño, et al., 2018) developed a methodology to evaluate visibility from point clouds in indoor environments using MATLAB. Their approach was similar to the current study (as will be described in section 4) in that they filled the space with voxels. The difference, however, is that they used a different software (MATLAB) and also used an indoor modeling scanner to generate the cloud points (Figure 27).

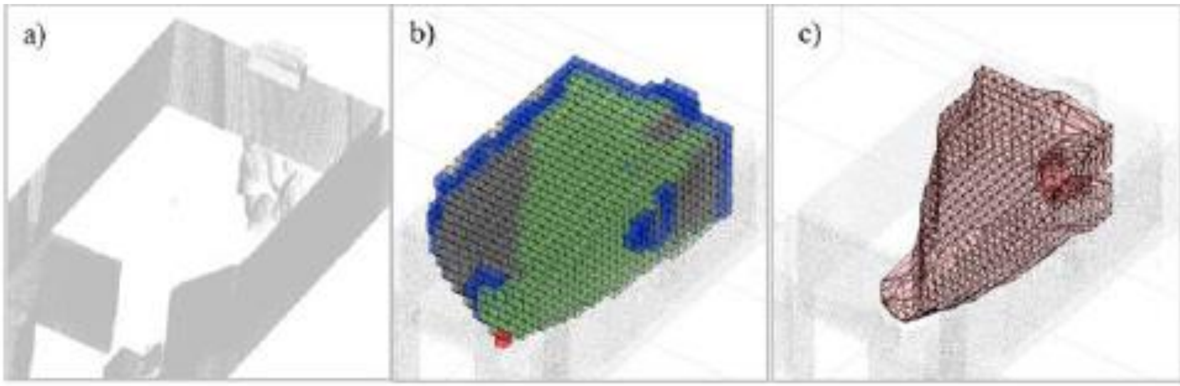


Figure 27: a) Point cloud, b) voxel representation, c) 3D isovist.

Dalton and his colleague's approach to generating a 3D isovist was to use laser scanning of real environments (Dalton, et al., 2015). They studied how the orientation of public displays can influence their noticeability and were the first to compare 3D isovist measures with empirical data (Figure 28). To conduct their study, they measured the volume of 3D isovists from each display in an academic building and compared that with data from a survey in which students were asked if they remembered seeing the words on the displays. They concluded that isovist volume seemed to most accurately predict the ability of people to recall the words presented on the displays.

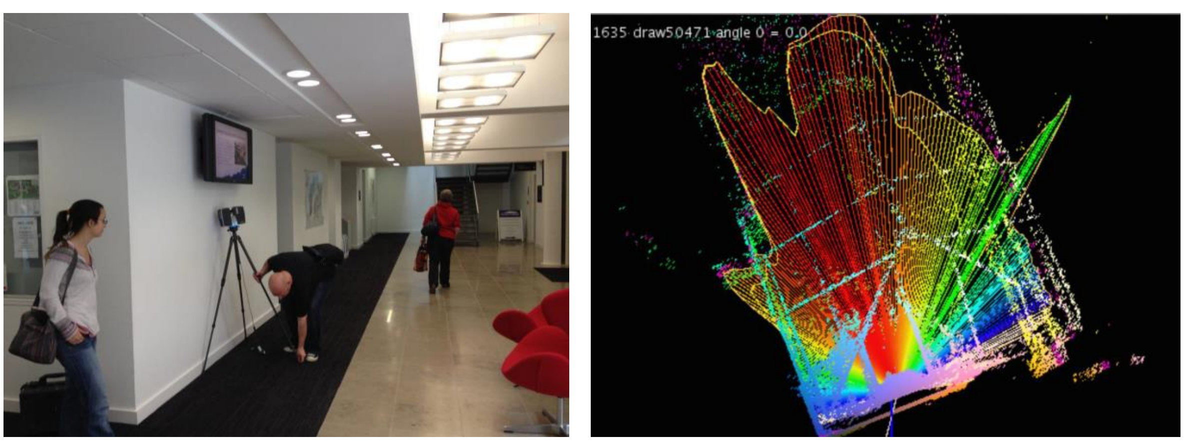


Figure 28: Laser scanning of the environment (left) and 3D isovist (right)

Bhatia and his colleagues researched on developing 3D isovists to identify salient regions in architectural spaces (Bhatia, Chalup and Ostwald, 2012). Using MATLAB in their study, the 3D isovists were generated by casting rays from the viewpoint, and measurements were based on the length of the rays. They analyzed CAD models of the Villa Savoye using this methodology and found that results of the saliency analysis of the Villa Savoye broadly correlate with several interpretations of the spatial identity of this building.

Sengke and Atmodiwirjo (2017) also tried to generate 3D isovist in a hospital inpatient ward to relate that to the patient experience. They used grasshopper to model the 3D visual field of patients. They reported this as an ongoing study and did not report any numerical data for the 3D isovist nor made any comparisons empirical data of patients' experience (Figure 29).

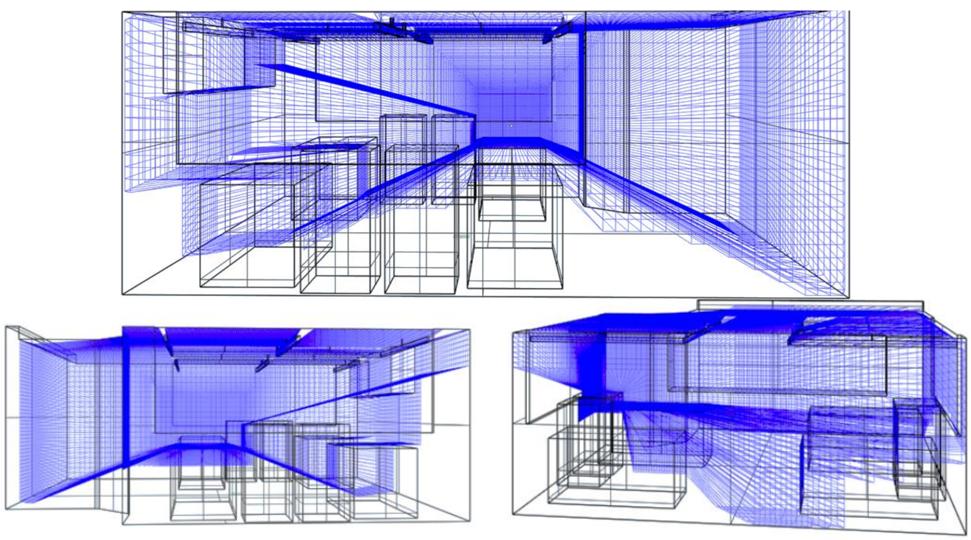


Figure 29: 3D isovist from a patient bed

Lonergan and Hedley (2015) proposed that 3D isovists can be applied to study privacy and surveillance in urban environments (Figure 30). Although, they did not conduct such a study and primarily modeled visual access among two high-rise buildings.

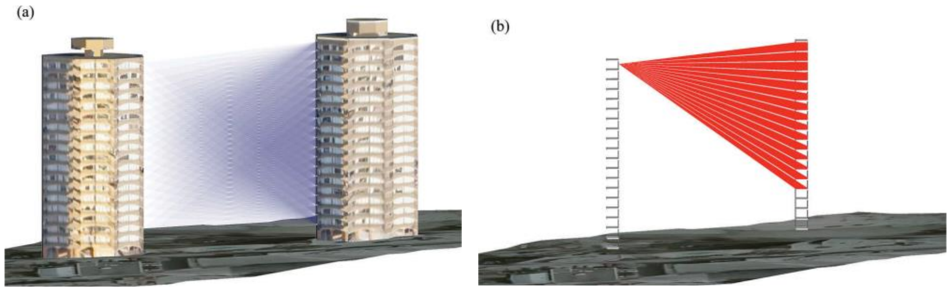


Figure 30: Analyzing 3D space for the study of privacy

As a part of an ongoing study, Li et al. (2016) tried to relate visual qualities of urban environments (isovist measures including area, perimeter, compactness, etc.) to people's emotions including a positive or negative feeling toward those spaces. Their study found that greater visibility within a space seems to be advantageous in causing positive emotions, indicating that people may prefer spaces with good vistas within a suitable distance and clearer boundaries.

In summary, although there have been a couple of efforts in recent years with a focus on 3D visibility analysis, this has not yet resulted in a development of any publicly available methods for three-dimensional analysis of space. The existing literature is mainly centered around methods of representation of 3D visual field with a few exceptions of studies that have tried to develop methods to measure 3D isovist and compare that empirical data. Based on this review of the literature, there is a need to develop a method for generating 3D isovist which allows for volumetric measurement of the visual field and compare that with data from users to understand the difference between 2D and 3D analysis and their relation to user experience.

2.3. An Understanding of Campus Environment

This section discusses the significance of student union buildings on college campuses as an important resource that has a role in increasing student recruitment and decreasing departure from college and reviews important design factors that contribute to building a successful student union building.

2.3.4. Higher Education and the Student Union Building

The college union was initially created to provide a social outlet for students in an environment that helped promote learning (Butts et al., 2012). Over time, these buildings grew to take on more roles and include more spaces to the point that today's union buildings have study spaces, coffee shops, lounges, bookstores, theaters, and places for recreational activities like bowling and billiards. For students, union building is a place where they can go to see other students and make connections. On many campuses, union buildings are among the first buildings that potential students visit and therefore make their decision about whether to enroll in college. Research consistently establishes the importance of student union buildings in not only attracting student enrollments but also keeping students on campus (Janisz, 2014). The section explains more about why and how student union buildings can reduce student departure from colleges based on theories of student integration and student involvement.

2.3.5. The Role of Union in Student Departure

The built environment can influence students' retention or departure on colleges, because physical place matters for student learning, creation of community, and for meeting higher education's civic mission (Rullman and Kieboom, 2012). Tinto (1993) discussed that prior research tended to think that student departure from college is a shortcoming in the individual characteristics and personal failure. Although there is some truth to this view, he explained that student departure is also under the influence of the institution since the individual behavior is a function of the environment. This can highlight the role of student union building as part of the institution of higher education in reducing student departure.

In his theory of individual departure from institutions of higher education, Tinto (1993) posits that social and academic integration can explain students' voluntary departure from colleges. He based his work on VanGennep's (1960) theory of rites of passage in which three phases occur when an individual joins a new group, including 1) Separation from the past, 2) transition and interaction with new setting and people, and 3) incorporation and adoption of the norms and expectations of the new group. He also refers to suicide as described by Durkheim (1951), as a phenomenon that can be analogous to college departure and arises when individuals are unable to establish membership within a community.

Tinto believes that in higher education, integration involves both social (personal affiliation and contact among students) and intellectual (academic and sharing of values) connections, and the individual's integration experiences reinforce persistence through the impact upon heightened intentions and commitments to the goal of college completion. On the other hand, negative or mal-integrative experiences serve to weaken the intention and thereby enhance the likelihood of leaving (Tinto, 1993). He further explains that when students are not integrating into the college community, they may be more involved with external communities whose values might confront or be at odds with those in college and therefore result in a departure from college. The more students are involved academically and socially, the more likely are they to become more involved in their learning and invest time and energy to learn.

Guiffrida (2006) further advanced Tinto's theory of student departure from a cultural perspective and explained that Tinto's assertion about students need to break away from past associations and traditions to become integrated into the college's social and academic realms might not hold true specifically about minority students, as they need their own specific motivations and need to be connected to their support groups once they arrive at college. He further explained that having this consideration, college faculty and staff who are aware of students' salient motivations can then effectively connect students to university social systems that fulfill these salient needs. For example, students who maintain collectivist societal values may benefit from early connections to ethnic/cultural student organizations that emphasize the fulfillment of collectivist needs for relatedness and social change (Guiffrida, 2006). To summarize, we can see the important role of student union buildings in providing the medium for students' social and intellectual integration in college and connecting those seeking relatedness to their peers.

The other theory that helps us in understanding the role of the student union in student departure is that of Astin's (1984), who proposes a student development theory based on student involvement in higher education. He hypothesized that the more involved the student is, the more successful he or she will be in college. He further explains that student involvement refers to the amount of physical and psychological energy that the student devotes to the academic experience, thus, a highly involved student is one who, for example, devotes considerable energy to studying, spends much time on campus, participates actively in student organizations, and interacts frequently with faculty members and other students (Astin, 1984). He asserts that this psychic and physical time and energy of students are finite and therefore every institutional policy and practice can affect the way students spend their time on campus, including issues like location and design of buildings and attractiveness of these facilities which can significantly affect how students spend their time and energy. Astin (1984) further reports the result of a longitudinal study of college dropouts and explains that every significant effect in student persistence could be rationalized in terms of the involvement concept as students who join social fraternities or sororities or participate in extracurricular activities of almost any type are less likely to drop out.

Concluding from Tinto's integration theory (Tinto, 1993), the cultural advancement to his theory (Guiffrida, 2006) and Astin's involvement theory (Astin, 1984), student unions have a major role in establishing the social connections for both bonding with peers and support groups and bridging to new and different groups, as well as providing a space for informal academic learning through housing student organizations and providing spaces for students to meet, mix and socialize as well as study. Attina (1989) explains that students, in order to locate themselves in the campus geography, seek to cut the larger campus down to knowable smaller parts or niches that help anchor them. This niche may be a club or organization or a familiar community on campus that shares similar views. Informal student groups and formal campus organizations are all institutional subcultures that assist students in making meaning of the college experience. They are powerful tools to the goals and purposes of higher education, what it means to be a member of the community, and how to go about the business of being a college student (Strange and Banning, 2015). Here we can see the role of the Union in providing a space for accommodating such activities and connections.

2.3.6. Environments that Foster Students Learning and Success

The campus physical environment impacts students experience, personal growth, and development (Banning and Kaiser, 1974). Rullman and Harrington (2014) believe that college unions are ideal physical environments for all members of the institutional family to be welcomed into meaningful interaction and relationship building, and for learning to be of the highest quality. Strange and Banning (2001) propose a hierarchy of environmental design that includes three levels of safety and inclusion, engagement, and a sense of community in designing environments that facilitates students' success (Figure 31). According to this model, an educational institution must first present an inclusive, safe, and secure environment for all students, so they can have a sense of belonging to the campus community free from threat, fear, and anxiety. Campus environments must also engage students in effective learning experiences that require taking on meaningful roles and responsibilities both in and out of the classroom. Having these two provides for conditions of community, where goals, values, and people come together, whether in the form of a class or a student organization.

Figure 31: Hierarchy of environmental design in campus. Source: strange and Banning, 2001

In order to support these three levels, Strange and Banning (2001) suggest that 10 kinds of spaces should exist on campuses (Table 5).

Table 5: Ten kinds of spaces for environmental design of a campus

Inclusion and Safety	1. **Welcoming**: Creating a sense of belonging and security for newcomers and visitors 2. **Inclusive**: Affirming identities and supporting expressions of self and other
Engagement	3. **Functional**: supporting key working tasks and activities 4. **Sociopetal**: encouraging open and spontaneous human interactions and encounters 5. **Flexible**: adapting to multiple purposes and participant imprints 6. **Esthetic**: inspiring a creative sensible and uplifting the human spirit 7. **Reflective**: encouraging quiet individual imagining and meaning-making 8. **Regenerative**: restoring energy and motivation for persisting

Community	9. **Distinctive:** creating unique and memorable impressions 10. **Sustainable:** supporting human experience through the right proportion, scale, and resource

Besides the three conditions of the environmental design of campus environment, Strange and Banning (2015) emphasize a sense of place and explain that a sense of place among students can connect to higher degrees of involvement in the academic life of an institution, issues of retention, attention, motivation, learning and academic achievement. The focus of the current research is to understand how physical design as one aspect of the environment can create inclusive and welcoming spaces where student engagement takes place and results in a sense of community.

2.3.7. Design of Union Buildings

Specific to the design of union buildings, Levy (2009) identifies the features for designing the student union of today as followings:

- Grand, inviting interior space (atria, stairways, balconies, ballrooms)
- Well-developed transparency mix (using glass to separate large space)
- Action/ activity (running water, areas for formal and informal activity)
- Light and sound (mix of low light and bright spaces)
- A sense of student (art, Furniture and facility components fitted to current constituents)

- Flexible, technical spaces (lounges, common spaces, meeting rooms, technically savvy facilities)
- A sense of spontaneous connectedness and comfort (spaces that engender true interpersonal connectivity)

Similar to these features, there are also other guidelines for the design of buildings such as the importance of wayfinding, sunlight and windows, design of halls, and corridors that influence social interactions, flexibility of furniture, issues of privacy and crowding, color, noise, lighting, temperature, availability of resources and staff, art exhibits, etc. (Kopec, 2012; Painter et al., 2013). Such features can be important for drawing students together in student union buildings as a location of community to interact and engage with one another.

It is important to note however that although these features are suggested for the design of union buildings, they don't guarantee the success of the design. There are examples like UWM union building which has a couple of these features (atrium and skylights) but is not considered the most successful and welcoming space. Also, it is one thing to include these features and guidelines in the design of union buildings, and another to understand how well students know about them and use them. These features can afford to create "sticky spaces" that draw people in and encourage them to linger, only if they lend themselves to being found by students, therefore the discoverability quality of spaces is another factor that needs to be considered when designing spaces. A space is discoverable when people know about it and be aware that it exists. This knowing may happen through different means of the college website, outreach events, other people talking about it, or just because the overall configuration of the building offers visual access to different parts of it and people have seen the spaces on their everyday path in the building. The current study hypothesizes that configurational characteristics of spaces is an important factor in students' awareness of them and the quality of discoverability of these spaces.

Conclusion

Student union buildings not only provide the services that students need but also have a significant role on college campuses as they facilitate students' learning and engagement. These facilities also play a role in enhancing feelings of belonging as well as attracting and retaining students (Janisz, 2014).

Rullman and Harrington (2014) believe that physical structures are the means by which the institution communicates nonverbally to its users about its values, vision, and capabilities. The physical environment of student union buildings should create safe places that facilitate students' engagement and access to resources. The current study focuses on the ways through which the physical aspect of a union building, through its configuration and visibility patterns, can accommodate activities, behaviors, and use of space by students. The next section studies the physical space and methods for analyzing the built environment which is thought to influence behavior and awareness of places.

3. METHOD

Besides defining discoverability as a quality imperative to the design of complex buildings, the current study also aims to understand how the discoverability of places is related to the internal building design. For this purpose, the study uses a mixed-method approach. Mixed-methods involve combining or integration of qualitative and quantitative research and data in a research study for the broad purposes of breadth and depth of understanding (Creswell, 2014; Johnson et al. 2007). The methods used in this study include a quantitative analysis of architectural floor plans based on space syntax methods as well as a qualitative approach to understanding students' experience of visiting the Union building and their familiarity with different places inside the building.

This research addresses that dealing with human perception and behavior is more complicated than it can be simplified in a cause and effect relationship. This study is trying to find correlations between the layout of the built environment with people's ability to discover places. Groat and Wang (2013) explain that any study seeking to clarify patterns of relationships between two or more variables or factors involved in the circumstances under study is considered a correlational research and count three general characteristics for this strategy. These characteristics and how they apply to the current study include:

1- A focus on naturally occurring patterns:

The current research seeks to study discoverability of places measured through student familiarity with those places in a student Union. The focus is on student familiarity as it naturally occurs based on the student experience of visiting the building.

2- The measurement of specific variables:

This study measures and quantifies various variables of interest including presence or lack of familiarity with each location, level of familiarity, and frequency of visits to those places. Besides these, the building floor plans will also be analyzed to derive measures that can describe the location and visibility of places.

3- The use of statistics to clarify patterns of relationships:

Using statistics, the current research studies the relationships between the results of the survey and the results from the Union building analysis. Students' ratings of familiarity with different places will be compared with the quantitative measures derived from analysis of the building's floor plan.

This study hypothesized that different factors can play a role in the discoverability of places including 1) the visibility of a place, 2) its function and users' need to find the place, 3) word-of-mouth or hearing from friends and social media, and 4) marketing efforts through emails, posters, and flyers that advertise for the place (Figure 32). Since the focus of the study is on characteristics of places and their physical and visual accessibility, the online survey asks about how students first came to know about each place, so it can control for other factors besides the visibility of the place.

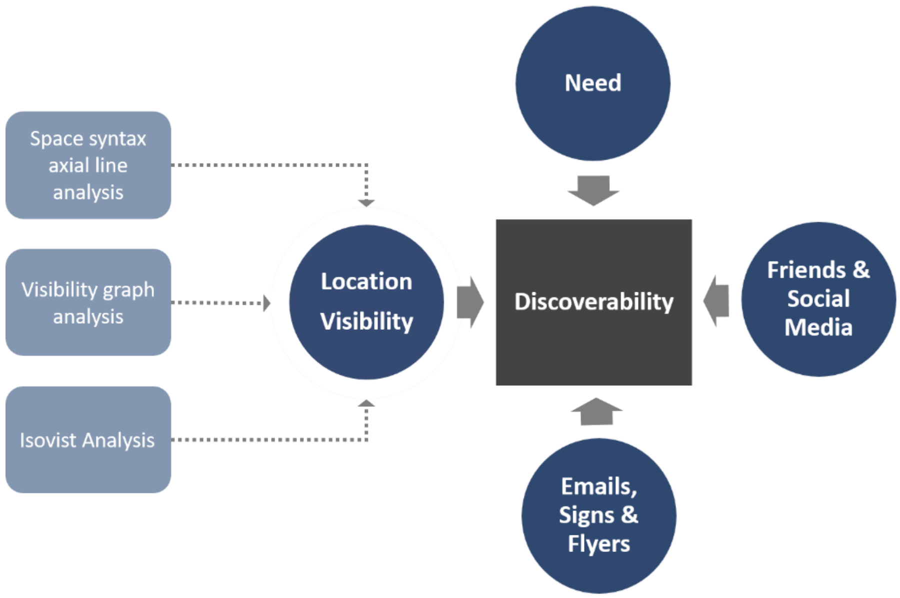


Figure 32: factors impacting discoverability of a place

3.1. Case Study and Research Site

To study discoverability and its relationship to the building layout, this research used the case of UW-Milwaukee student union building. Although it can be argued that having multiple case studies can deal with concerns about generalization, it is believed that when conducting a case study aimed at building initial understandings of a situation, any single case might work (Lazar, Feng, and Hochheiser, 2017). As Sarvimaki (2017) explains, a single case study is an investigation on various factors of one setting, therefore it can uncover complex dynamics of the setting.

The student union building at the University of Wisconsin-Milwaukee was first built in 1956 with an area of 15,000 square feet (Karambelas, 2017). Since then, the building has gone through three stages of expansion as the student body extended over time. Stage one expansion started in 1963 with more than 90,000 square feet added to the 15,000 square feet, making the union more than just a bookstore. Stage two and three of expansion took place in 1972 and 1987, respectively adding another 200,000 square feet to the already 100,000 plus square foot union (Karambelas, 2017). Today the Union operates in five levels, offering a variety of resources to students like restaurants, coffee shops, student associations, involvement, and organization offices, lounges, the art gallery, cinema, bookstore, etc. The UWM Union building is an interesting site to study in that it has a variety of places and resources for students, but since the construction and expansion of the building took place at different phases, these resources were gradually added to the building along with acquiring and arrangement of various additional space.

3.2. Plan Analysis

As mentioned earlier in the literature, this study uses different methods to analyze and describe the physical environment of the student union building. These methods include space syntax axial line and visibility graph analysis to calculate the visual connectivity and integration values of different spaces. The connectivity and integration values were calculated for an axial map of separate floors as well as connected floors, and VGA of separate floors. The study also uses other measures including step depth and isovist to compare to the result of student survey and their ratings of familiarity with places. Step depth was calculated to represent how visually deep places are located from entrances to the floor and the 2D isovist area is a measure of the visible area from each place in the building.

One other measure that this study calculates is 3D isovist volume. As mentioned earlier, one of the shortcomings of the existing methods for visibility analysis is that they do not allow for three-dimensional analysis of the visual field, therefore this study developed a method to evaluate the volume of space that is visible from each location on the floor plan, which is equivalent to 3D isovist. As will be introduced later, the current study used Grasshopper plugin in Rhinoceros to develop a definition for 3D analysis of architectural space.

The analysis of the student union building plans enables to capture certain aspects of the physical environment into a data format. This study uses these multiple measures to then evaluate which one(s) can best relate to students' ratings of familiarity with spaces.

3.3. Online Survey

The survey questionnaire is one of the most frequently used methods of data collection. Groat and Wang (2013) note that the great advantage of survey questionnaires is that they enable the researcher to cover an extensive amount of information- from demographic characteristics to behavioral habits, and even opinions or attitudes on a variety of topics- across a large number of people in a limited amount of time. Another advantage of surveys is that they are relatively objective and offer a formal way of obtaining information that is more or less free from biases, values, and predispositions of the researcher (Marans, 1990).

An online survey was distributed among students at the University of Wisconsin-Milwaukee to collect their input on how well they know the union building. For this purpose, a list of places that are located in the building was presented to students and the survey asked them to identify if they know about such places in the building (or have discovered it) and how familiar they are with those places. It is assumed in this study that if a place is discoverable, more students know about it.

The question that might be raised here is that sometimes people know places not just because they can visually and physically access those, but because they need to find those places. In other words, those are places that are discovered because of their function, and/or location. An example of which in the student union buildings is when students want to buy food, pick up their transportation card, attend an event, etc. Besides responding to needs, there are also other factors contributing to the discovery of a location including hearing from friends or social media, or finding about a place through posters, signs, flyers, or other marketing efforts. To account for these factors, the survey asks respondents how they first came to learn about the places that they earlier identified as familiar. By controlling for these other factors that impact the discovery of a place, we can study the role of the visibility and physical layout of the building in facilitating or hindering discoverability.

The survey also asked questions about the kind of activities for which students go to the Union and their top destinations in the building. The difference between this question with the earlier ones in the survey asking about familiarity is that this is more aimed at students and how each individual one uses the building, whereas the earlier questions were centered around places.

Finally, a set of questions were asked to find about students' perceptions of inclusion and safety in the Union building. The results from these questions were used to study if there is a correlation between the number of places that students know about with their perception of inclusion and engagement opportunities in the Union building.

To analyze the survey results and compare them with results from the building analysis, different statistical tests were performed including T-test and Welch's ANOVA analysis. These tests and their application in the study will be elaborated in the data collection and findings section. The study uses Microsoft Excel and Minitab programs to complete the statistical analysis.

Considering that the study involved research on human subjects and distribution of the questionnaire among students, the study protocol and the online questionnaire were submitted for a review to the University of Wisconsin – Milwaukee Institutional Review Board (IRB). The result of the review suggested that the study has no more than "minimal risk" for participants in the online survey and would, therefore, be categorized as exempt.

4. FINDINGS & DISCUSSION

4.1. Plan Analysis

The spatial characteristics of the UWM Union building was quantitatively measured to be compared to empirical data from survey questions. For this purpose, a set of measures including connectivity, integration, step depth, isovist area, and volume was calculated as explained in section 2.1. Connectivity and integration measures were calculated for both axial maps and VGA maps. Regarding axial maps, measures were calculated for individual floors as well as connected floors as a whole building.

4.1.1. Axial Line

Axial lines are defined as the longest and fewest lines of sight. Initial space syntax methods were based on axial lines, which led to graph measures constructed around the topological properties. The axial line is a powerful form of representation and one that may well be reflected in individual spatial decision-making (Emo, 2014). Axial line analysis was conducted for the Union building and results are presented in Table 6. Analysis was done once for separate floor plans and a second time for connected floors. Unlike the axial map analysis for separate floors that is performed by the Depthmap software, there is no automated methods developed for generating the axial map of the connected floor plans. Therefore, staircases and elevators on each floor were manually used as connectors between floors (Figures 33 and 34).

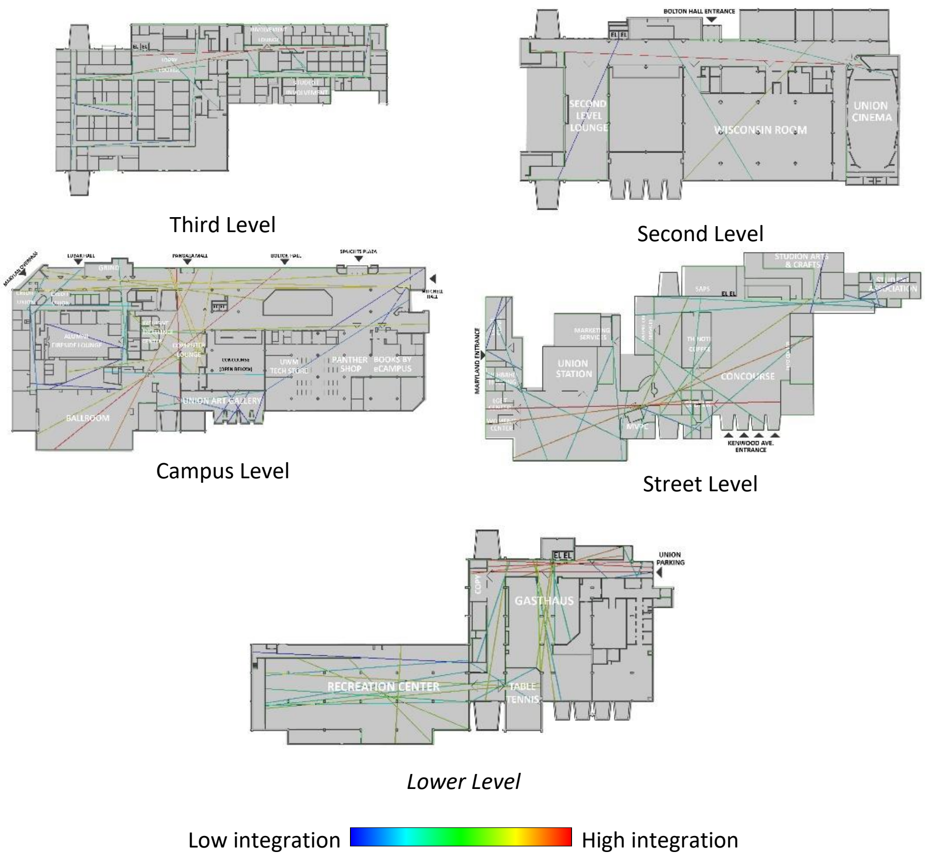


Figure 33: Axial line integration for separate floors

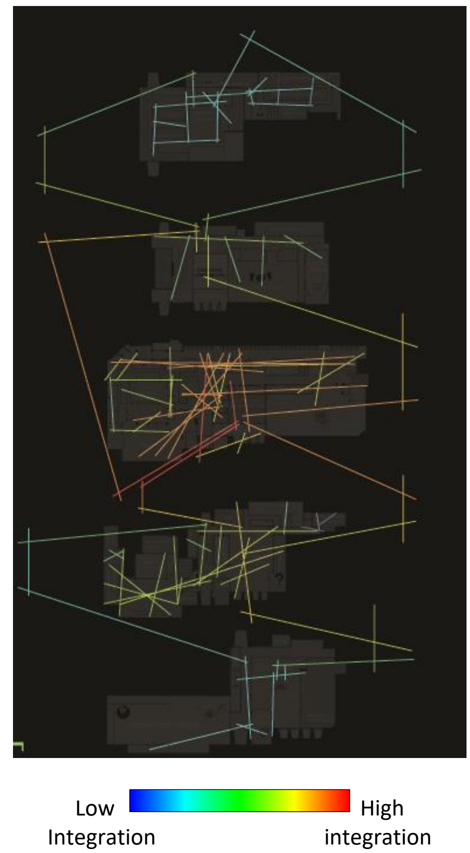


Figure34: Connected floors Axial line integration

4.1.2. Visibility Graph Analysis

Visibility Graph Analysis (VGA) encodes the inter-visibility of multiple observation points that are distributed regularly over the whole environment (Turner et al., 2001). Figure 35 Shows VGA analysis conducted on the Union floor plans. Unlike axial maps, VGA does not provide individual values for each specific space, therefore, to derive quantitative measures for each area, the average value of all the cells was calculated. VGA results for each place are presented in Table 6.

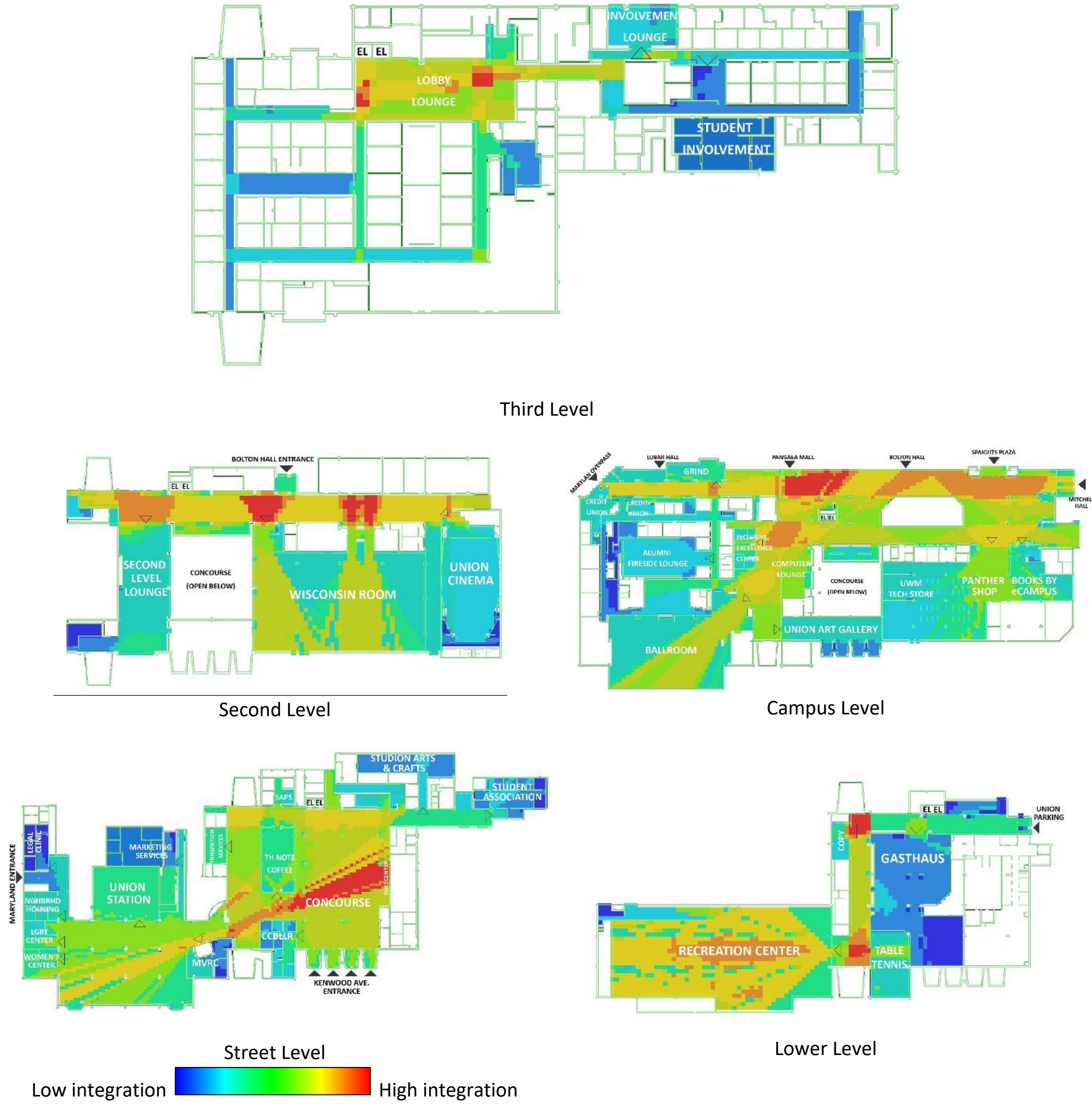


Figure 35: VGA integration analysis

4.1.3. Visual Step Depth

Step depth illustrates the number of steps (changes of direction) it would take to get from a selected location to any other location in the graph. The selected location has step 0. All locations directly visible from the selection have step 1; all locations directly visible from those at step 1, have step 2, and so on throughout the graph (Pinelo, Turner, 2010).

The entrances to each floor were selected and a step depth analysis for all locations on the floor was conducted. The entrances are marked with dark blue (step depth 0) in Figure 36 And include the entryway to the floor from elevators, stairs, or the entry doors. Step depth results for each place are presented in Table 6.

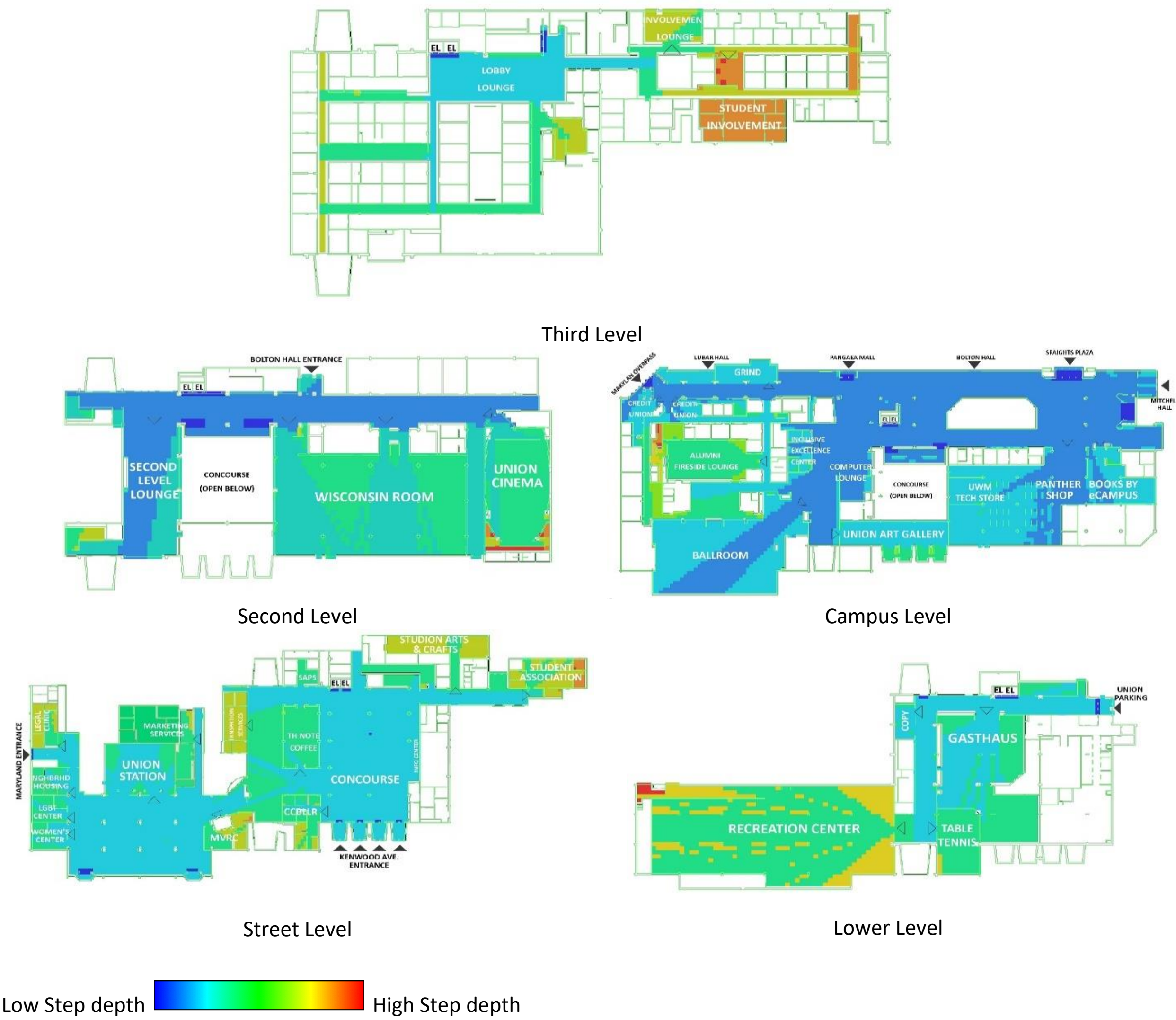


Figure 36: Step depth analysis

4.1.4. 2D Isovist

The visible space or isovist area was calculated from each location in the building to compare to survey data. This measure was calculated using Rhino-Grasshopper and the existing isovist component developed in the plugin. Figure 37 demonstrates a sample 2D isovist for the Information Center at the Union. The result of the isovist area for each location in the building is presented in Table 6.

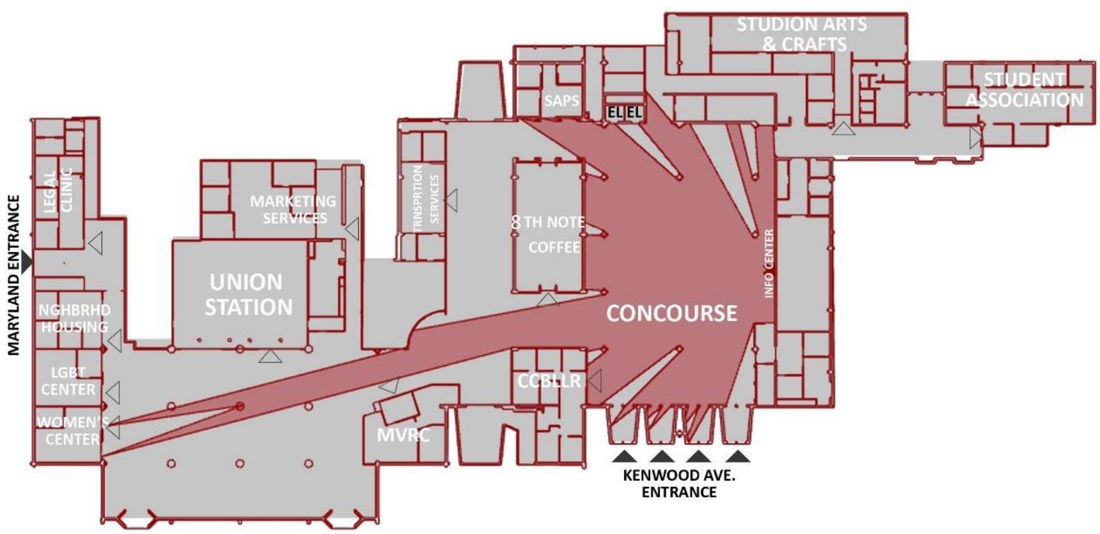


Figure 37: 2D isovist

4.1.5. 3D Isovist

This method is developed using the concept of voxels. Voxel is the 3-Dimensional equivalent of a pixel. Using voxels allows to break objects down to the smallest pieces of shape. Voxels are often used in medical imaging and terrain imaging to represent data that is very complex and computationally intensive. The current study applies a voxel analysis approach to the construction of 3D isovists. In this approach, the space is first filled with voxels and the goal is to construct a 3D isovist by finding voxels that fall into the visible portion of space from a viewpoint. To start, lines are drawn between viewpoint and voxels' center points (Figure 38). Lines intersecting with visual barriers like wall surfaces are excluded and the rest of the sightlines are used to produce voxels that make up the 3D isovist volume.

In this approach, voxels are created so that they fill up the whole space and have no or minimum voids among them. The definition is developed so that by changing the size of voxels their number is adjusted on the floor plan. This definition needs five main inputs to be inserted by the user: the floor surface, visual barriers, viewpoint, voxel size, and number of voxels to fill the space in the Z-axis. If this number is selected 1, the definition will produce a 2D isovist as a result.

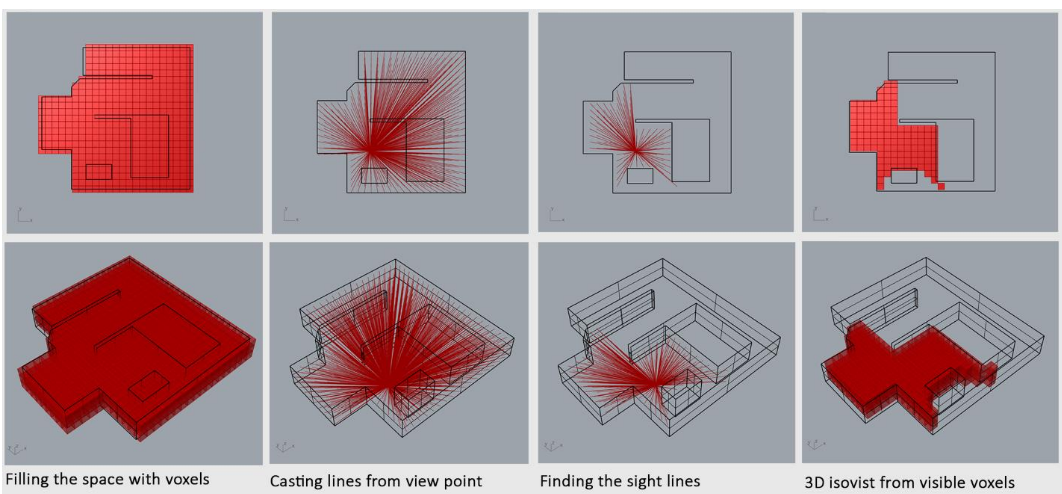


Figure 38: Constructing 3D isovist using voxels

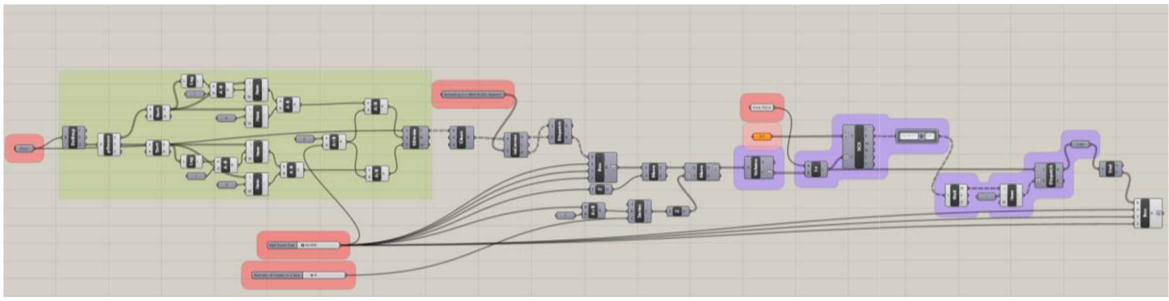


Figure 39: 3D isovist definition in Grasshopper

One advantage of using voxels is to control the resolution of a spatial analysis when complex data or computation is involved. This is illustrated in the following figures which are examining an isovist in a hypothetical setting. As we can see, the processing time more than doubled when resolution becoming two times more accurate.

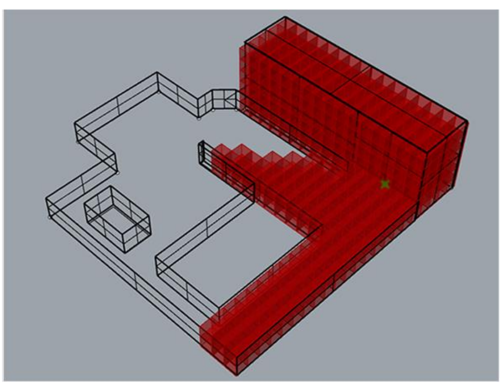


Figure 40: 3D isovist: 4’ voxels. Processing time: 5s

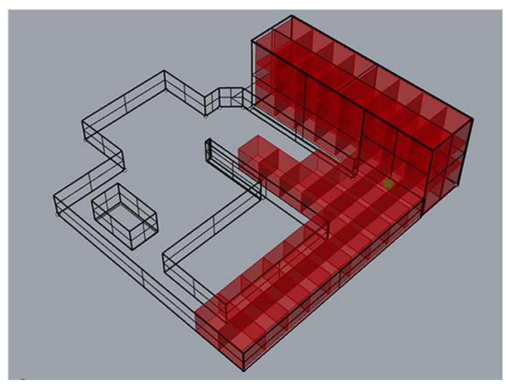


Figure 41: 3D isovist: 8’ voxels. Processing time: 2s

Figure 42 demonstrates a sample 3D isovist for Information Center at the Union. The result of isovist volume for each location in the building is presented in Table 6.

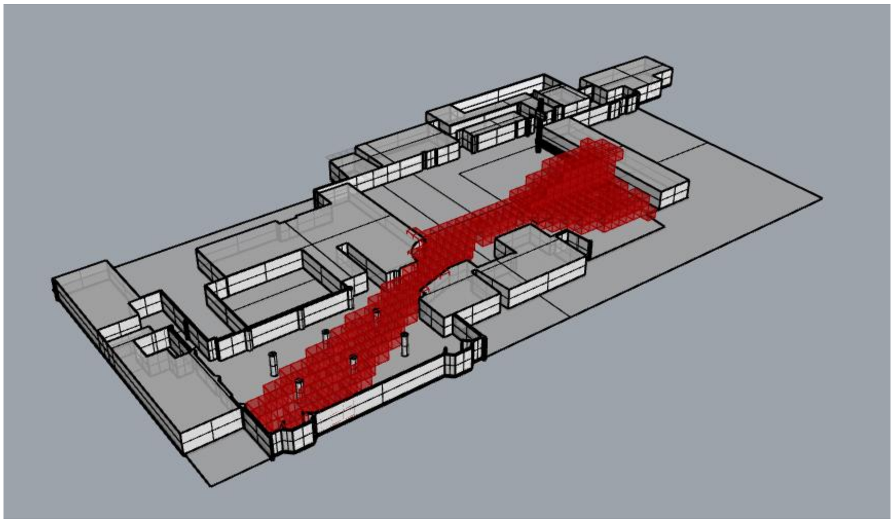


Figure 42: 3D isovist

The results of the building analysis conducted for different places in the Union are all presented in Table 6. Values in the table are color-coded for an easier identifying of highs and lows. The red color shows larger values, while blue represents smaller values. The results presented in this table were then used to compare to the results of the online survey to understand which one of the analysis methods can best relate to students' responses of the discovery of places.

Table 6: Building plan analysis results

	Separate Floors Axial integration	Separate Floors Axial Connectivity	Connected Floors Axial integration	Connected Floors Axial Connectivity	Step Depth from All entrance	VGA Integration	VGA Connectivity	3D Isovist	2D Isovist (Sq ft)
The Union Station (Food on Kenwood street level)	3.9	16.0	0.6	4.0	1.0	6.5	1224.0	99792.0	8255.0
Union Information Center	3.5	14.0	0.7	12.0	1.0	9.2	1653.0	173232.0	153.0
Ballroom	3.3	14.0	0.8	12.0	1.0	5.6	980.0	65664.0	6221.0
LGBT Resource Center	3.3	13.5	0.6	6.0	1.0	5.7	548.0	95472.0	7669.0

Women's Resource Center	3.3	13.0	0.6	9.0	1.0	6.2	736.0	96552.0	6896.0
Copy Center	2.9	14.0	0.4	4.0	1.0	4.8	122.0	18576.0	1880.0
Student Involvement	2.8	6.3	0.4	4.5	2.1	4.1	70.6	42768.0	2238.0
Inclusive Excellence Center	2.6	10.5	0.8	12.0	1.0	4.8	138.0	98496.0	11254.0
UW Credit Union	2.4	8.5	0.7	1.0	1.0	4.5	110.0	35424.0	1695.0
8th Note Coffee Shop	2.2	6.5	0.6	3.0	1.0	6.1	331.0	105840.0	3813.0
Grind Coffee Shop	2.1	8.0	0.7	7.0	1.0	5.4	329.0	126576.0	10461.0
Neighborhood Housing	2.0	7.0	0.6	5.0	1.0	5.2	398.0	39312.0	3184.0
Military and Veteran Resource Center	1.9	6.5	0.6	2.5	1.5	5.0	350.0	79920.0	5567.0
Panther Shop	1.8	4.0	0.8	12.0	1.1	6.1	850.0	110500.0	9100.0
Gasthaus	1.8	8.3	0.4	1.5	1.0	3.4	293.0	12528.0	1475.0
Center for Community-Based Learning (CCBLR)	1.8	5.0	0.6	2.0	1.0	4.4	111.0	114048.0	6914.0
Transportation Services	1.7	7.0	0.5	1.0	2.0	7.1	654.0	48384.0	3853.0
Books by eCampus	1.7	3.0	0.7	5.0	1.3	6.0	681.0	108000.0	8432.0
Union Art Galley	1.6	3.6	0.8	2.0	2.0	3.9	230.0	42768.0	2238.0
Wisconsin Room	1.6	2.5	0.6	1.0	2.0	6.1	739.0	45360.0	3737.0
UWM Tech Store	1.5	2.0	0.7	4.0	1.5	5.0	549.0	8000.0	6250.0
Union Rec Center (Bowling & Table Tennis)	1.4	7.3	0.4	2.0	2.0	6.4	845.0	9504.0	815.0
Student Association Offices	1.4	4.0	0.4	2.5	3.4	2.9	38.1	16416.0	1684.0
Alumni Fireside Lounge	1.3	2.0	0.6	2.0	3.0	3.5	304.0	6912.0	11254.0
Legal Counseling	1.2	2.0	0.5	2.0	2.0	3.0	59.0	11664.0	618.0
Union Cinema	1.1	2.0	0.6	1.0	2.0	3.7	256.0	77328.0	6107.0
Studio Arts and Crafts Center	1.0	2.0	0.6	1.0	2.0	3.5	161.0	22032.0	555.0

4.2. Online Survey

To collect data from students, a questionnaire was administered through Qualtrics during the month of February 2020 (The questionnaire is presented in the Appendix). The invitation email containing the online survey link was sent on February 4, 2020, and the link remained open for 20 days. During this time students received two email reminders for completing the survey. The invitation email was successfully sent out to 9,988 students at UW-Milwaukee. This email list was obtained from the UWM Union administrators. Although no exact data is available for the demographic breakdown of the sample population, the list comprised of email addresses of about two quartiles of each group of undergraduate- freshman students, undergraduate- not freshman students, and graduate students based on enrollment in Fall 2019 at UWM. Therefore, the sample email list comprised of nearly half of the student population enrolled in Fall 2019. Based on the conversation with the Union administrators, data from other surveys that had been sent out to UWM students showed that the average response rate for this campus was 6 to 8 percent, with a 75% completion rate.

Upon the survey closing date, a total of 874 students responded to the survey. Figure 43 shows the distribution of responses, which was at its maximum after students received the initial invitation email and reminder emails. Based on data from the Qualtrics website, 874 students started the survey, 630 of whom completed it, resulting in a 72% completion rate.

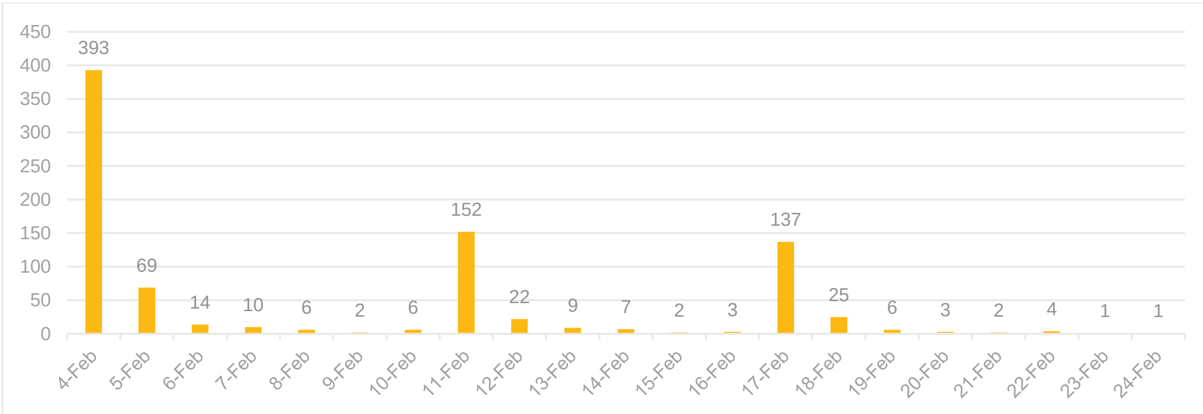


Figure 43: Distribution of response submission during data collection from the online survey (Total 874 responses)

4.1.1. Respondents' Demographics

Based on the Office of Assessment and Institutional Research at UWM, a total of 24,018 students were enrolled for the Fall 2019 semester at UWM. Table 7 provides demographic information for students enrolled in the Fall 2019 semester (Office of Assessment and Institutional Research at UWM, 2020). This data was used to compare to respondents' demographics to evaluate if the sample respondents to the online survey can be a good representative of the student population at UWM.

Out of the total number of survey respondents, 61% were women and 35% were men (Figure 44). Regarding respondents' year in school, the largest group related to Fourth-year students and Graduate students at 24% and 23% of respondents, respectively. Most of the respondents were White (71%) with Asian and Hispanic/Latino students as the next two large categories, with 9% each.

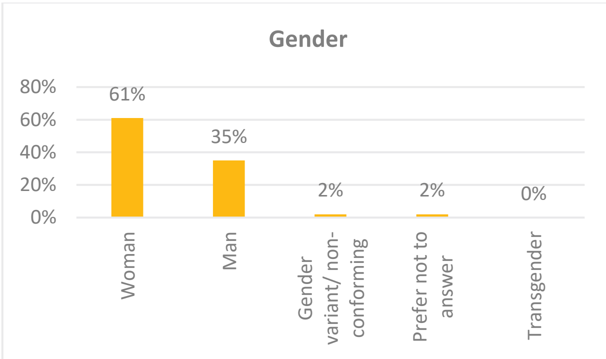


Figure 44: Respondents' Gender distribution (n= 630)

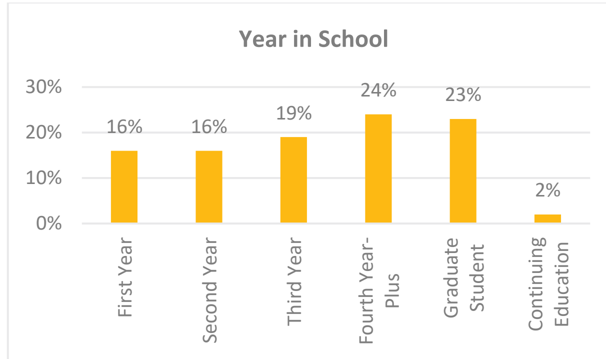


Figure 45: Respondents' Year in School distribution (n= 630)

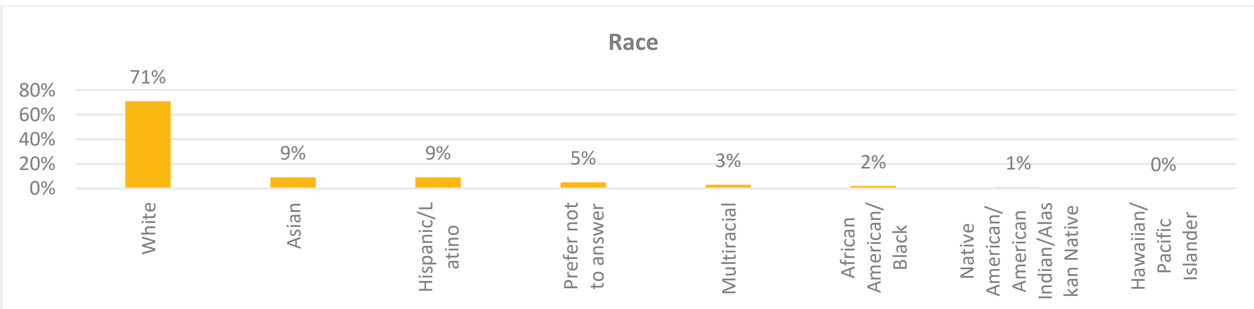


Figure 46: Respondents' Race distribution (n= 630)

A summary of the survey respondents' demographic is presented in Table 7 in comparison with demographic data of students enrolled in Fall 2019 at UWM. A comparison between data presented in the Table reveals that although there are some dissimilarities, there is not a substantial difference between survey respondents' demographics and the demographic of students at UWM. Therefore, we may conclude that the sample respondents can be an acceptable representative of the student population at UWM.

Table 7: Demographic breakdown of survey respondents and students enrolled in Fall 2019 at UWM (n= 630)

		Survey Respondents		Fall 2019 Enrolled students	
		Count	***Percent***	***Count***	***Percent***
Gender	Woman	316	61%	13,228	55%
	Man	179	35%	10,790	45%
	Transgender	1	0%	N/A	N/A
	Gender variant/ non-conforming	12	2%	N/A	N/A
	Prefer not to answer	11	2%	N/A	N/A
Race	White	368	71%	15745	66%
	African American/Black	11	2%	1595	7%

	Asian	45	9%	1366	6%
	Hispanic/Latino	44	9%	620	3%
	Multiracial	17	3%	3149	13%
	Native American/American Indian/Alaskan Native	4	1%	85	0%
	Hawaiian/Pacific Islander	1	0%	N/A	N/A
	Prefer not to answer	27	5%	N/A	N/A
Nationality	American	492	96%	22773	95%
	International	20	4%	1,245	5%
Year	First Year	85	16%	3,780	16%
	Second Year	83	16%	4,248	18%
	Third Year	97	19%	4,111	17%
	Fourth Year-Plus	127	24%	5,937	25%
	Graduate Student	118	23%	4,630	19%
	Continuing Education	10	2%	1,312	5%

4.1.2. Overall Familiarity with the Union building

Students in the survey were asked to rate their overall level of familiarity with the UWM Union building on a 4 point scale (-2= Very unfamiliar, +2= Very familiar). This question was specifically of interest since the survey asked if students knew about different places in the building, therefore, a low overall familiarity with the building could relate to a low awareness of places.

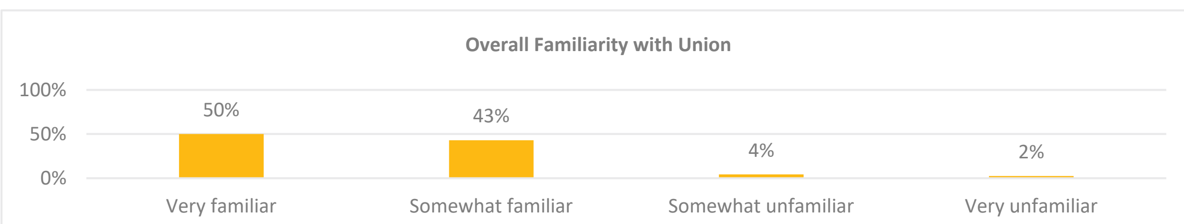


Figure 47: Respondents overall familiarity with Union (n= 630)

A total of 93% of respondents indicated that they were very or somewhat familiar with the building. Calculating the average familiarity score based on the coded values also resulted in a 1.39 average familiarity score for all respondents. This score represents a level of familiarity above 'Somewhat familiar'(+1). To understand if different demographic groups had different levels of familiarity with the building, the responses were broken down based on students' gender, year in school, the school they attended, and race. Group means in each category were then compared using Analysis of Variance (ANOVA). Because the compared groups had different sample sizes and variances, a Welch's ANOVA test was used instead of a classic ANOVA test. Welch's ANOVA is an alternative to the classic ANOVA and can be used even if the data violates the assumption of homogeneity of variances (Moder, 2010).

The threshold for statistical significance was set to 0.05. Analysis results revealed no significant difference in the average familiarity score based on respondents' gender (F(2, 176.11)=1.60, *P*=0.21), year in school (F(5,86.55)=0.71, *P*=0.62), school (F(10, 98.55)=0.94, *P*=0.50) or race (F(5, 23.03=1.07, *P*=0.41).

Table 8: Welch's ANOVA results for student familiarity with the union building

		Count	***Mean***	***F***	***P-value***
Gender	Woman	327	1.34	1.60	0.21
	Man	224	1.41		
	Gender variant	56	1.51		
Year in School	First Year	85	1.50	0.71	0.62
	Second Year	83	1.40		
	Third Year	97	1.50		
	Fourth Year-Plus	127	1.36		
	Continuing Education	10	1.50		
	Graduate Student	118	1.35		
School	Architecture and Urban Planning	19	1.28	0.94	0.50
	College of Engineering & Applied Sciences	53	1.35		
	College of Health Sciences	32	1.26		
	College of Letters & Science	139	1.51		
	College of Nursing	29	1.54		
	Helen Bader School of Social Welfare	29	1.36		
	Joseph J. Zilber School of Public Health	8	1.00		
	Lubar School of Business	66	1.49		
	Peck School of the Arts	49	1.44		
	School of Continuing Education	49	1.25		
	School of Information Studies	18	1.18		
Race	African American/Black	11	1.55	1.07	0.41
	Asian	45	1.20		
	Hispanic/Latino	44	1.50		
	Multiracial	17	1.59		
	Native American/American Indian/Alaskan Native	4	1.25		
	White	366	1.40		

*significant at 95% confidence level

Students were also asked about their frequency of visits to the Union during a semester. Forty-two percent of respondents said they visit the building three times a week or more with another 32% visiting the building once or twice a week. Therefore, a total of 74% of respondents indicated that they visit the building at least once a week (Figure 48).

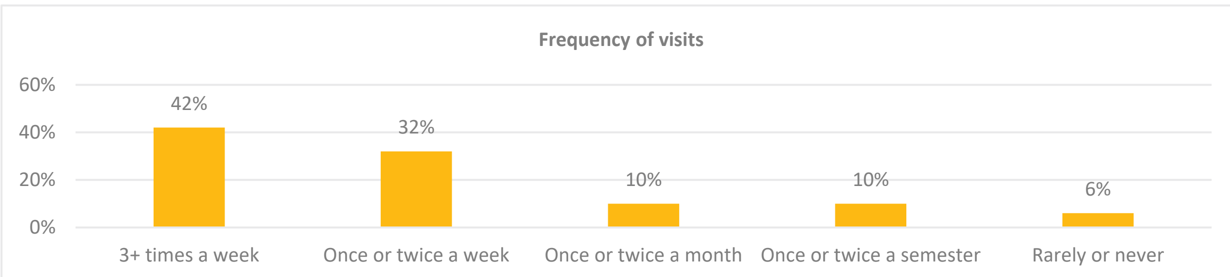


Figure 48: Frequency of visits to the Union (n= 630)

Regarding the amount of time students spend in the Union during a typical visit, 38% of respondents indicated that they spend less than 30 minutes in the building during each visit with another 36% spending between 30 minutes to one hour. A total of 26% of students also spend more than one hour during their typical visit to the building (Figure 49).

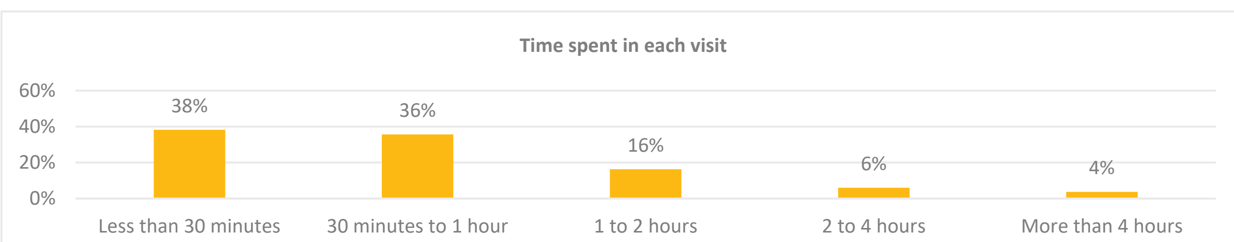


Figure 49: Average time spent during a typical visit to the building

The survey asked students to identify the reason why they visit the Union building. This question tried to gather data on the perceived role of the Union and to help draw a profile of the building regarding how it is being used. As Figure 50 presents, the major reason that students identified for visiting the building was getting something to eat or drink (21%). This makes sense as the Union is the major dining location on campus with a variety of food places and different coffee shops.

Surprisingly, the second biggest reason for visiting the building was to pass through it and arrive at other destinations (19%). In other words, almost one-fifth of the visits to the union is simply not because of the Union itself, but because the building plays an important role in connecting buildings on campus. Although this may not be the ideal function that a union building would want to serve, however, on the positive side, this presents an opportunity for programming the Union to direct the attention of the through passers and utilize anchors that makes them want to linger as opposed to simply pass through the building.

Another 15% of responses related to visiting the building to spend time between classes, and 11% to attend events. The Union building seems not to be the best spot for social activities as based on the responses, only 10% of visits related to hanging out with friends and 1.5% for meeting new people. The recreational aspect of the building does not either seem to be its competitive advantage since only 8% of responses related to visiting the building for the purpose of resting, relaxing, or recreating. The 1.5% other category mainly related to visiting the Union to attend work, using the parking, or using services located in the building, like the Credit Union, Union Cinema, Panther Shop, or picking up tickets for different events.

Understanding and collecting data regarding the purpose of visits to the Union building not only provides information about the building itself, but it also provides benchmark data to compare to other buildings and find what aspects of the building needs to be improved and more invested in.

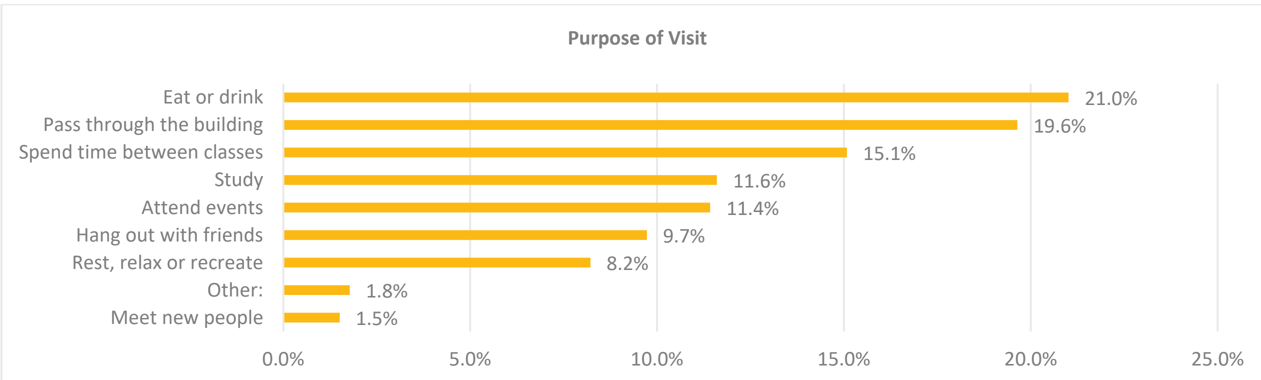


Figure 50: Purpose of visits to the Union building

4.1.3. Place Familiarity, Visit, and Discoverability

Besides the overall familiarity with the Union, the survey also focused on individual destinations in the building. To study these individual places, the second section of the survey provided respondents with a list of places in the Union and asked 1) if respondents' knew about those places and their level of familiarity with them, 2) their frequency of visit to the places and 3) how they first came to know about the place. As mentioned earlier in Figure 32, there are a few possible reasons, besides the visibility of a place, why people may have discovered a place, which includes the need a place serves, word-of-mouth, and place marketing. The question about students' source of discovery of places was specifically important for controlling these other possible reasons why people may be familiar with a destination.

To start with familiarity with each place, respondents were asked not only to identify if they know about each of the places in the Union but also indicate how familiar they are with them. Figure 51 summarizes the results for each place in the Union. By asking about familiarity or knowing about a place, this question intended to get at if respondents have yet discovered those places or not. The words familiarity and knowing about are being used interchangeably with the word discovery here.

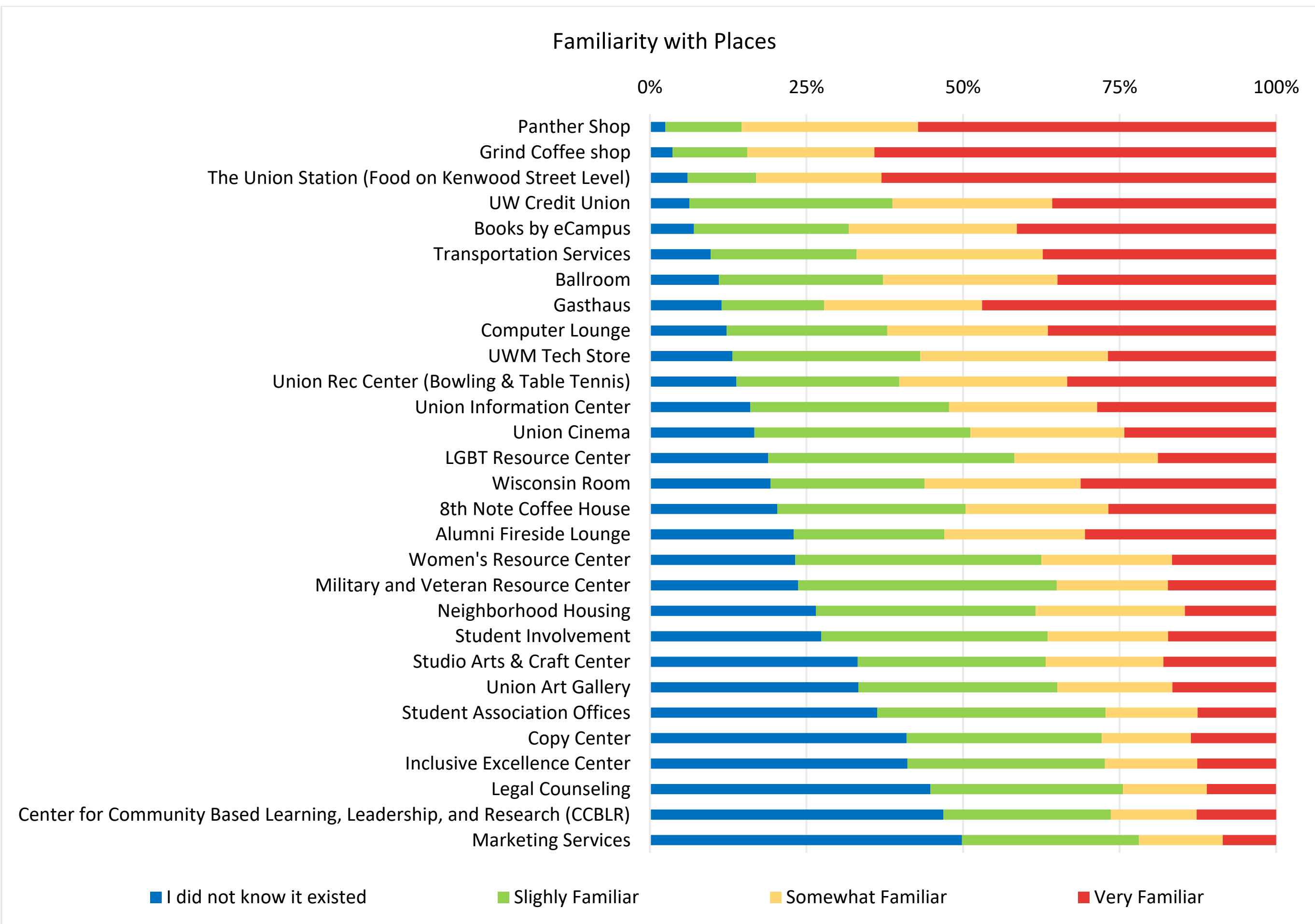


Figure 51: Familiarity with different places in the Union (Unfamiliar  Very Familiar)

Based on the results, Marketing Services, Center for Community Based Learning (CCBLR), and Legal Counseling were the top three unfamiliar locations for students with 50%, 47%, and 45% percent of respondents not knowing that such places exist in the Union. The next highly unfamiliar (undiscovered) places for students were the Inclusive Excellence Center, Copy Center, and Student Association offices.

Although one could anticipate that students not seek and know about Marketing services, Legal Counseling, or copy center in the Union, yet the overall low familiarity with CCBLR (Center for Community Based Learning, Leadership, and Research), Inclusive Excellence Center, and Student Association offices may be not expected as these places provide opportunities for learning and a place for the community to come together. By looking at Figure 51, we can see that Student Involvement, which is another place that provides involvement opportunities for students is also located towards the bottom of the list, with 27% of students not knowing about such a place in the Union and another 36% being slightly familiar with it. Students' low rate of discovery of these places may have various reasons, however, revisiting Table 6 after these results, we can see three out of these 4 resource centers (CCBLR, Student Association offices, and Student Involvement) did not score the highest in terms of visibility measures either.

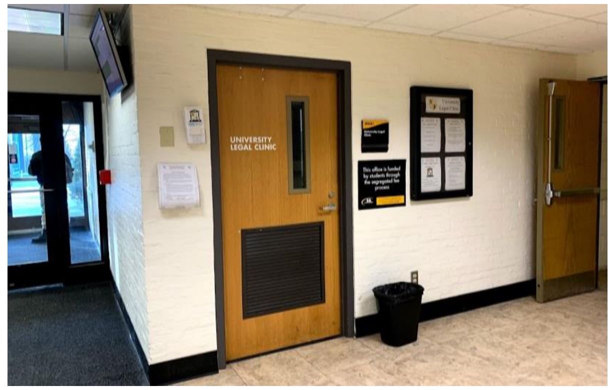


Figure 52: Center for Community Based Learning, Leadership, and Research (CCBLR)

Figure 53: UWM Legal Counseling

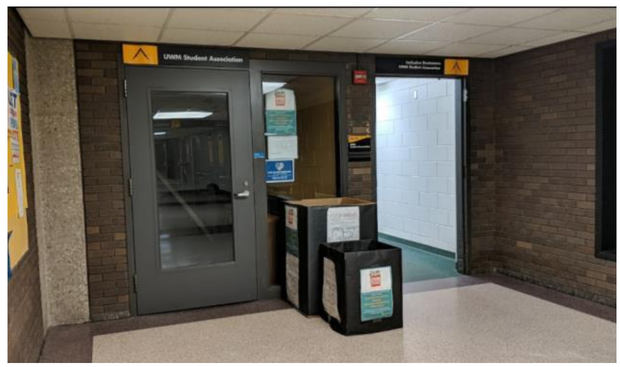


Figure 54: Inclusive Excellence Center

Figure 55: Student Association Offices

Figure 56: Entrance to Student Involvement and student organization offices on the third level

The most familiar places for students, on the other hand, were Panther Shop, Grind Coffee Shop, The Union Station (Food on Kenwood Street Level), and UW Credit Union with respectively 98%, 96%, 94% and 94% of respondents being familiar with those places. Unlike resource and learning centers in the Union, which mainly involve voluntary and optional activities, these highly familiar destinations are places that serve necessary activities, like providing food and drink options or serving a specific need of students like banking or picking up items and supplies they need. Looking at Table 6, again we can see besides the necessary functions these places serve, how they are also located in prime areas of the Union in terms of visual accessibility.

Figure 57: Grind Coffeeshop

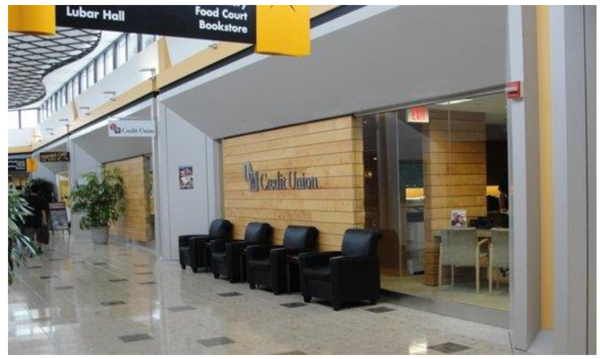
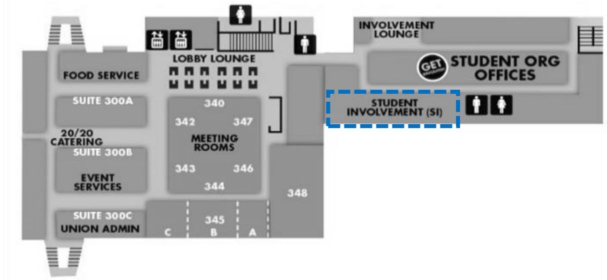


Figure 58: UW Credit Union

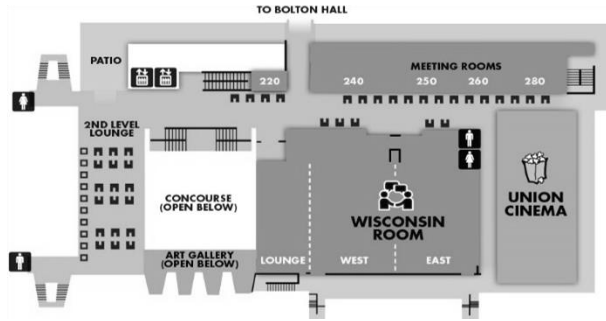
Figure 59: UWM Book Store

Figure 60: UWM Panther Shoo

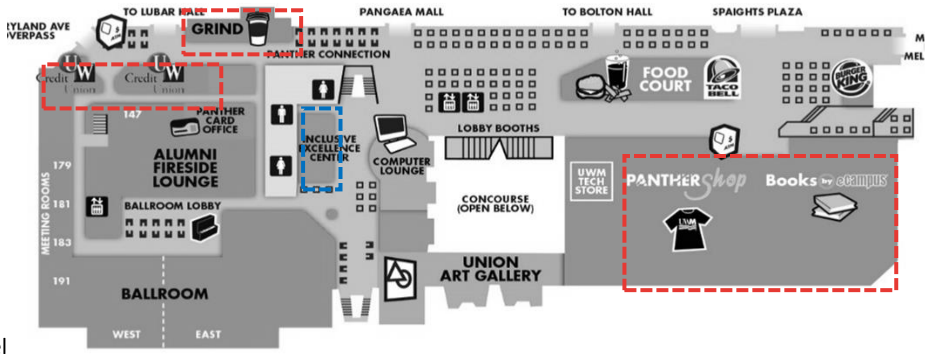
Figure 61 presents the location of these highly discoverable and undiscoverable places on the Union floor plans based on the survey results. While the least discoverable places are almost scattered in the building, the highly discoverable ones are mainly located on the campus level and by the entrances. This can raise an interesting question of whether these highly discoverable destinations serving students' necessary needs, also need to be located in prime locations in the building.



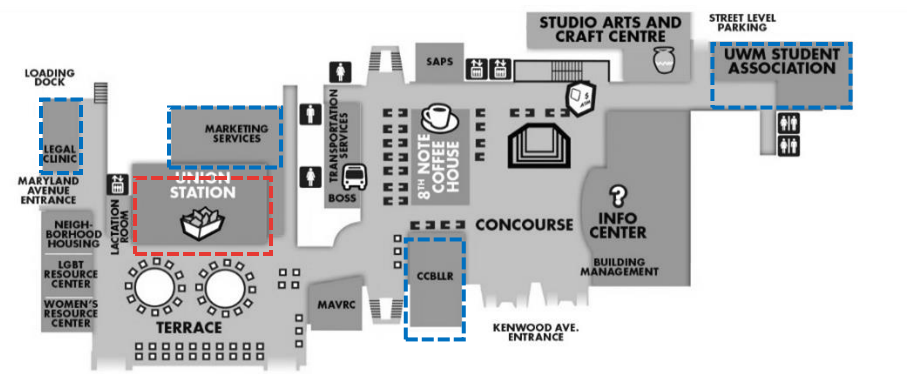
Third Level



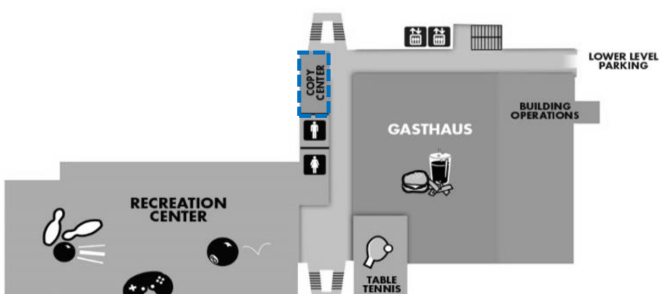
Second Level



Campus Level



Ground Level



Lower Level

Figure 61: Topmost and least familiar places for students (Most familiar: red, Least familiar: blue)

As mentioned earlier, students' high or low ratings of the discovery of each of these places could relate to any of the four factors of discoverability presented earlier in Figure 32. It could be because of the need the place serves, its location and visibility, marketing (signs, email, posters), or just how popular it is among students (word-of-mouth). To understand this, we need to look at the results of the two following questions, regarding respondents' frequency of visit to those destinations and how they have come to discover the place. These results will be presented later in this section.

To further understand if there are any differences between respondents to the familiarity question based on respondents' demographics, the total number of places that each respondent identified as familiar was calculated out of the total 29 places. This included the number of places that each respondent had marked as slightly, somewhat, or very familiar. These values were then compared based on students' gender, year in school, school, and race.

Table 9 summarizes the results of the Welch's ANOVA test for comparing the average number of places that different groups are familiar with. Based on the results, the average number of places that respondents had identified were significantly different based on respondents' gender ($F(2,31.10)=7.81$, $P=0.002$). To understand where the difference lies, a Games-Howell post hoc test was conducted. The post hoc pairwise comparison further revealed that on average, gender variant respondents (Mean=26.27) were familiar with significantly more places in the Union compared to men (Mean=22.28, $P=0.003$) or women (Mean=22.81, $P=0.008$). It is important to note here that although the results were statistically significant, there were only 11 gender-variant respondents, which is quite a small group to base a finding on.

Regarding the other demographic categories, there was no significant difference between the average number of places identified by different groups of respondents based on their year in school (F(5,67.61)=1.06, *P*=0.39), school (F(10, 92.05)=0.96, *P*=0.49) or race (F(5, 22.65=0.74, *P*=0.60).

Table 9: Welch's ANOVA results for average number of familiar places in the Union

		Count	Average number of familiar places	F	*P*-value
Gender	**Gender Variant**	11	26.27	7.81	0.002*
	Man	175	22.28		
	Woman	308	22.81		
Year in School	First Year	84	21.83	1.06	0.39
	Second Year	82	22.04		
	Third Year	92	22.97		
	Fourth Year	124	23.57		
	Graduate Student	116	22.53		
	Continuing Education	8	22.75		
School	Architecture and Urban Planning	18	22.61	0.96	0.49
	College of Engineering & Applied Sciences	49	21.80		
	College of Health Sciences	31	22.03		
	College of Letters & Science	137	23.13		
	College of Nursing	27	23.59		
	Helen Bader School of Social Welfare	28	22.36		
	Joseph J. Zilber School of Public Health	7	23.00		
	Lubar School of Business	62	21.97		
	Peck School of the Arts	48	24.73		
	School of Education	47	23.21		
	School of Information Studies	17	23.24		
Race	African American/Black	11	23.73	0.74	0.60
	Asian	45	22.11		
	Hispanic/Latino	44	22.11		
	Multiracial	17	24.41		
	Native American/American Indian/Alaskan Native	4	20.00		
	White	366	22.10		

*significant at 95% confidence level

A sub-analysis was also conducted on students' average number of familiar places based on the response they provided to a question earlier regarding the amount of time they spent in the building during a typical visit. Table 10 presents the results of this analysis which shows the more students spent time in the building during each visit, the higher became the average number of places they were familiar with (had discovered) as well as their overall average familiarity score with the building. Although the differences presented in the Table are small, yet it shows an increasing trend in familiarity score with an increase in the average amount of time spent in the building.

Table 10: Respondents familiarity with the Union based on the amount of time they spent during a typical visit to the building

Average time spent in each visit	***Number of respondents (n)***	***Average number of familiar places***	***Overall average familiarity score with the building***
Less than 30 minutes	111	20.81	1.23
30 minutes to one hour	41	21.87	1.47
1 to 2 hours	215	22.92	1.56
2 to 4 hours	236	24.05	1.54
More than 4 hours	25	22.08	1.60

Besides the percent of respondents who had any level of familiarity with (or had discovered) each place, Figure 62 shows the average familiarity scores for places based on students' responses on their level of familiarity. To calculate the scores, responses were coded as numbers on a zero to 3 scale (0= I did not know it exists, 3= Very familiar). The results from calculating average scores turned out to be quite similar to the results from calculating the percent of people familiar with each place. Similar to the previous results, Grind Coffee Shop, The Union Station, and Panther Shop were places that received the highest average familiarity scores. On the other hand, Marketing Services, Legal Counseling, and Center for Community Based Learning (CCBLR) had the least respondents' average familiarity scores.

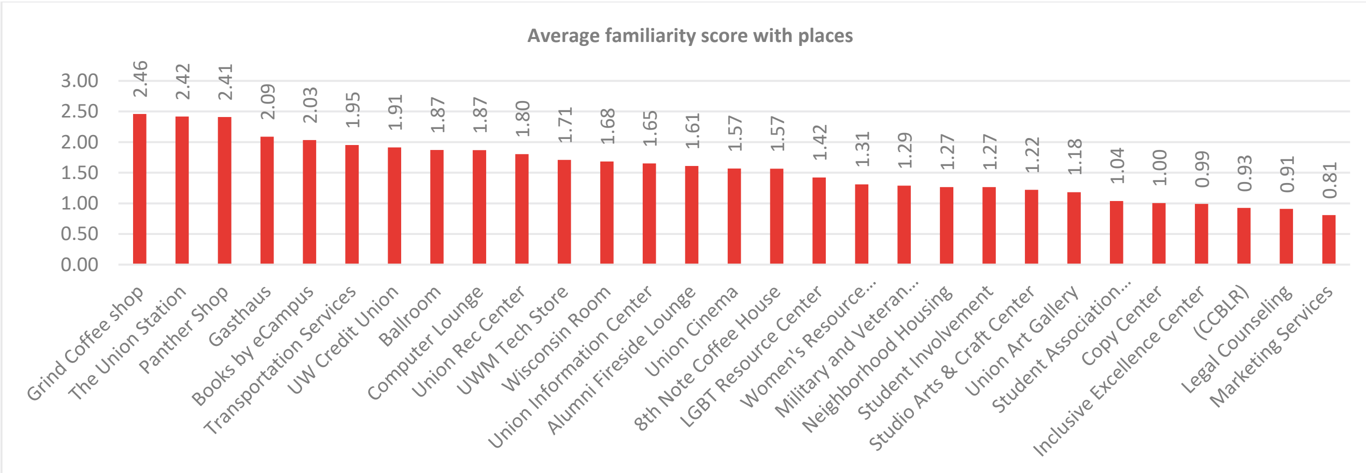


Figure 62: Average familiarity score with each place

Students were also asked about their frequency of visits to each place in the building. As Figure 63 illustrates, the topmost frequently visited locations in the building included the Union Station, Panther Shop, and Grind Coffee Shop, all of which respond to students' necessary activities like dining or buying supplies and essentials. The three places were also the same top three that most students knew about (Figure 51). Conversely, the least frequently visited places were Military and Veteran resource center (MVRC), Marketing Services, Inclusive Excellence Center, Legal Counseling, Women's and LGBT Resource Centers, CCBLR, and Student Association offices. Although it can be argued that some of these places may be serving a niche population among UWM students, yet seeing the resource and community places like Inclusive Excellence Center, CCBLR, and Student Associations among the least discovered and least visited presents their role for the average UWM student.

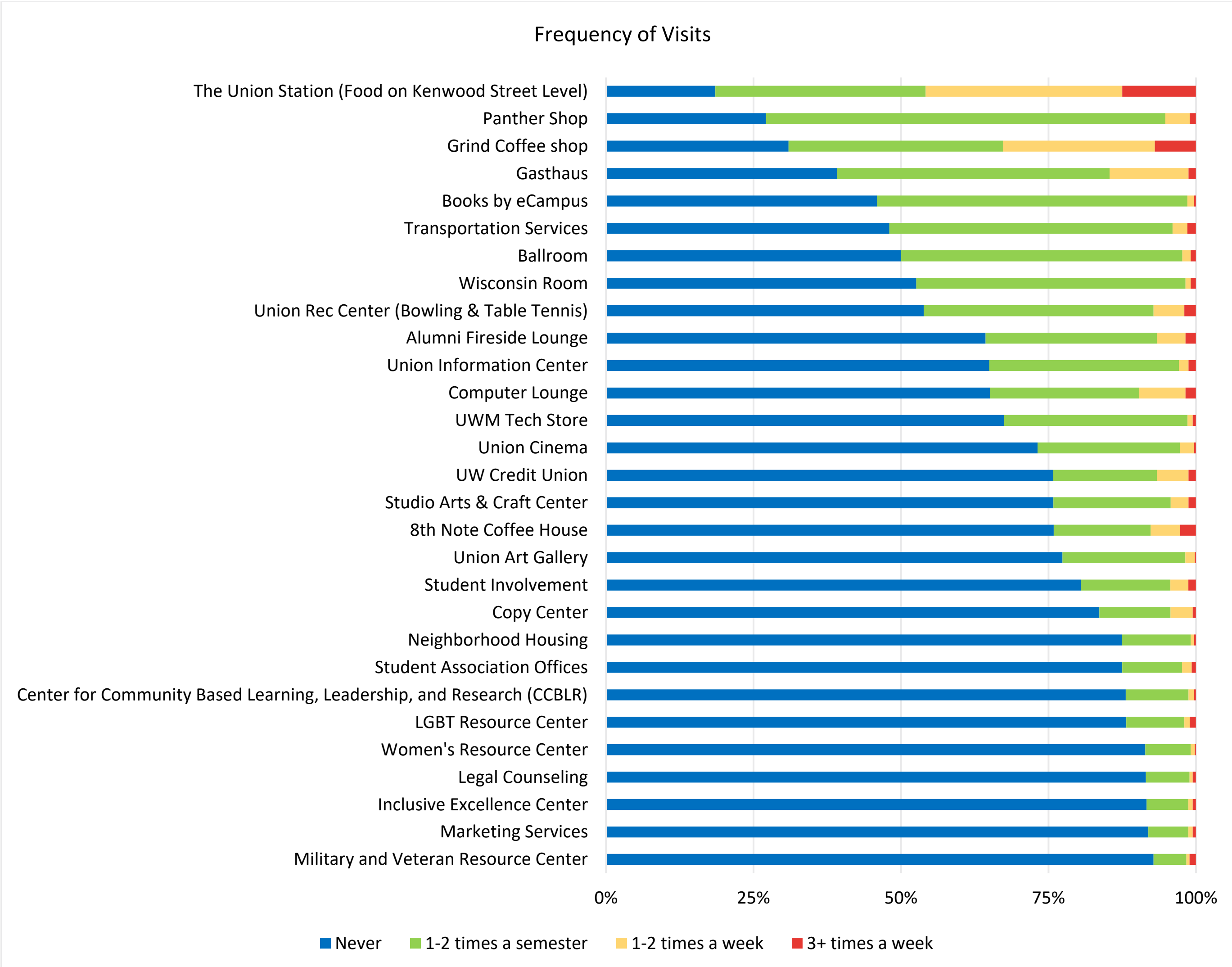


Figure 63: Frequency of visits to different places in the Union (0 visits 3+ visits a week)

To study the relationship between familiarity and frequency of visits, two methods were adopted. In the first one, the average scores for each data set were calculated and a correlation analysis was performed on average scores in Excel. Correlation coefficients fall within a range of-1.00 (a negative correlation) to +1.00 (a positive correlation) and a correlation coefficient close to 0 indicates no consistent linear relationship between variables.

Table 11: Average familiarity and visit score for places in the Union

	Avg Familiarity Score	Average Visit Score
Grind Coffeeshop	2.46	1.09
The Union Station	2.42	1.4
Panther Shop	2.41	0.79
Gasthaus	2.09	0.77
Books by eCampus	2.03	0.56
Transportation Services	1.95	0.58
UW Credit Union	1.91	0.32
Computer Lounge	1.87	0.47
Ballroom	1.87	0.53
Union Rec Center	1.8	0.56
UWM Tech Store	1.71	0.35
Wisconsin Room	1.68	0.5
Union Information Center	1.65	0.39
Alumni Fireside Lounge	1.61	0.44
Union Cinema	1.57	0.3
8th Note Coffee House	1.57	0.35
LGBT Resource Center	1.42	0.15
Women's Resource Center	1.31	0.1
Military and Veteran Resource Center	1.29	0.1
Student Involvement	1.27	0.25
Neighborhood Housing	1.27	0.14
Studio Arts & Craft Center	1.22	0.3
Union Art Gallery	1.18	0.25
Student Association Offices	1.04	0.16
Copy Center	1	0.21
Inclusive Excellence Center	0.99	0.1
Center for Community Based Learning (CCBLR)	0.93	0.14
Legal Counseling	0.91	0.1
Marketing Services	0.81	0.1

To calculate the average scores, responses to the two questions of ‘Familiarity’ and ‘Frequency of visit’ were coded on the same range from zero to 3 (frequency of visit; 0= Never visit the place, 3= 3+ times visits in a week) (Familiarity; 0= I did not know it exists, 3= very familiar). The calculated scores are presented in Table 11. The results showed a high positive correlation between average familiarity scores and average visit scores, with a correlation coefficient of 0.88. This can indicate that if people know more about a place, they visit there more often, while lower familiarity with a place came along with a lower frequency of visit to that place.

Another way to look at familiarity and frequency of visit was to focus on the percent of respondents who had any level of familiarity and who had visited the place at least once. To better visualize the relationship between the two, Figure 64 maps these percentages for both familiarity and frequency of visits on the same graph.

Places in the graph are color-coded for easier identification of their functions. Places like Union Station, Grind coffee shop, Gasthaus, and 8th note coffee house which provide food and drink options and create an opportunity for social gatherings of students are marked with red. Areas like the Rec center, Fireside lounge, and the Union Cinema which allow for restorative activities are marked with green. Resource centers are marked with pink and other involvement opportunities are presented with yellow color. Areas that provide services to students like the Credit Union, Panther shop, copy center, etc. are marked with blue).

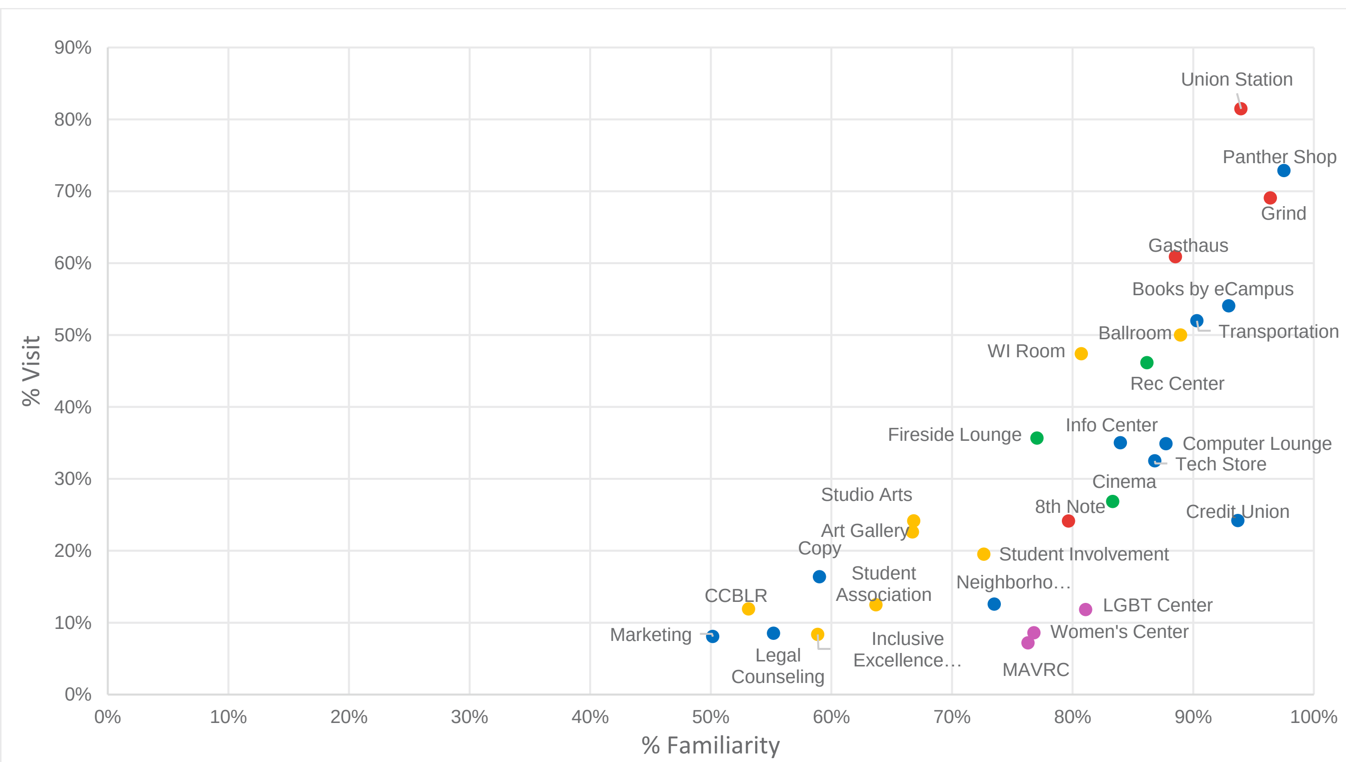


Figure 64: Plotting places based on % respondents with some level of familiarity and at least one time visit during a semester (Red: Social activities, Pink: Resource Centers, Green: Restorative activities, Blue: Service areas, Yellow: Involvement Opportunities)

This Figure shows the relationship between familiarity and visit to each of the places in the Union. As mentioned earlier, there is a relatively high correlation between the two data sets. The interesting points in Figure 64 are places where a high percentage of people know about but have a low visit scores. The most extreme case that can be seen here is the LGBT resource center. This means that although this place may not be serving a *need* for a lot of students at UWM, yet a lot of people somehow know about this place, which makes it discoverable. The same holds for Women's resource center and Military and Veteran Services (MAVRC). As will be presented later, a high number of respondents indicated that they learned about these places through visibility, which is in line with the results from Table 6. This can relate to the location of these places being located in a highly visible area of the plan and also adjacent to the heavily used Union Station, which is among the most familiar and highly visited places in the Union. These three places being discoverable for students presents an interesting case. Having them in a highly visible area despite their role in serving a niche population can have a symbolic meaning and reflect the UWM campus values.

Figure 65: LGBT and Women's resource center

Figure 66: Military and Veterans Resource Center (MVRC)

Another place that seems to have the privilege of being highly discoverable, while not receiving a lot of visits is the UW Credit Union. As Figure 64 shows, almost 95% of respondents knew about this place, while only 25% had ever visited there, which can relate to its prime location in the building being highly visible. This can raise a question of whether this is a programmatically correct decision as other places that provide involvement opportunities like Student Involvement, Student Association Offices, CCBLR which are important resources for the success of students are not scoring as good as the Credit Union.

In the third set of place-based questions, students were presented with the list of places in the Union one more time (except for places they identified they did not know exist) and were asked to specify how they came to know about them. The study identified four ways of discovering a place through 1) visibility of a place 2) the need it serves 3) word-of-mouth or hearing from friends and social media, and 4) advertisement and marketing efforts through email, signs, or posters. This question could, therefore, be used to control for other means of discovery except visibility and use the results to compare with results from the visibility analysis of the building.

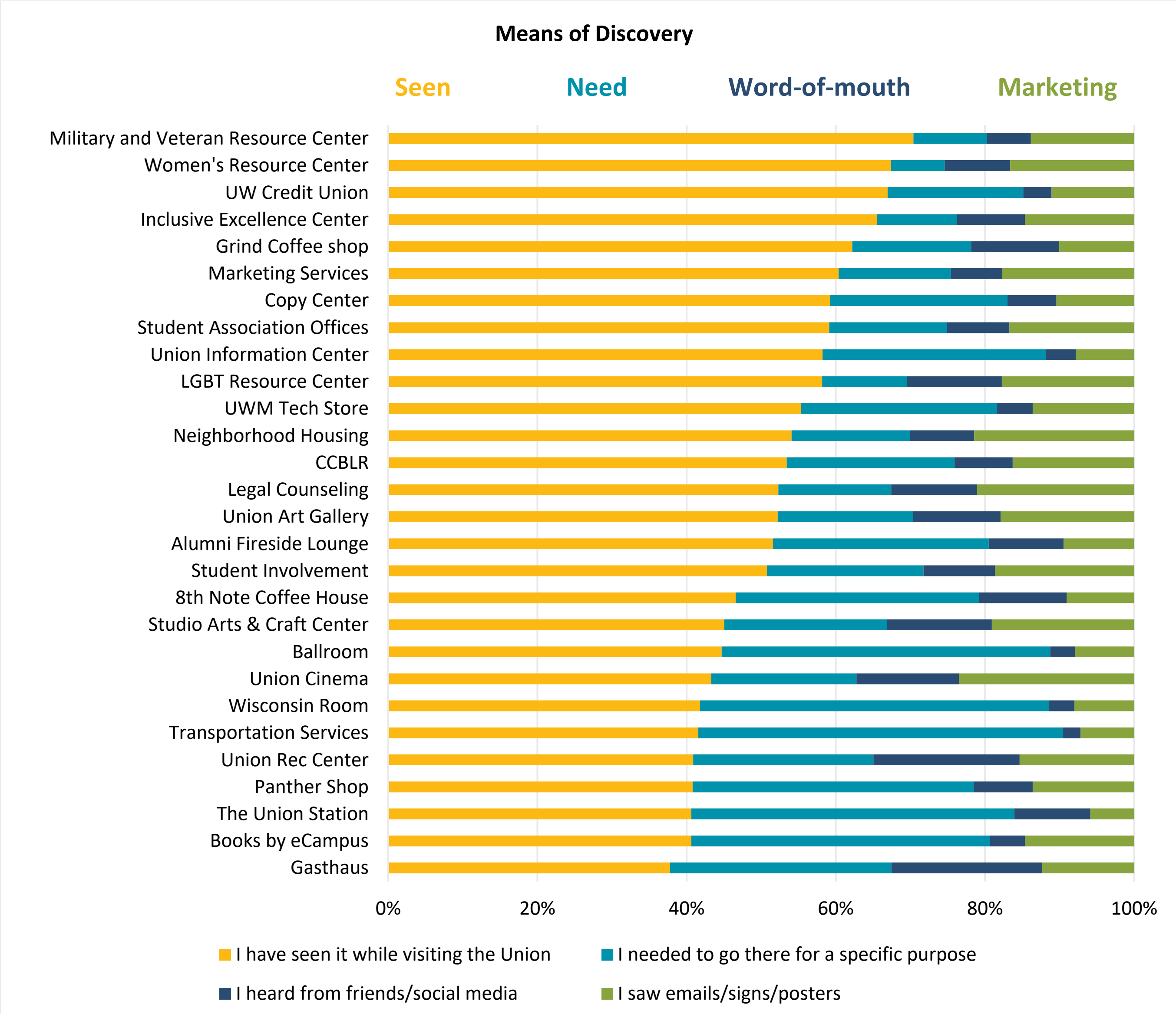


Figure 67: Means of discovering a place

The survey results for the question of discoverability are presented in Figure 67. Based on the responses, the top three places in each category were:

1- Visibility: Military and Veteran Resource Center, Women's Resource Center, UW Credit Union

2- Need: Transportation Services, Wisconsin Room, Ballroom
3- Word-of-mouth: Gasthaus, Union Rec Center (Bowling & Table Tennis), Studio Arts & Craft Center
4- Marketing: Union Cinema, Neighborhood Housing, Legal Counseling

One conclusion that can be drawn from the Figure is that places like Transportation Services which are mainly discovered through the need they serve, do not have to be located in the highly visible areas of the Union as students who need to find those places will find them anyway.

Although different places received different ratings of discovery means, to understand the overall average weight of each means in the discovery of places, average scores were calculated for all places. Table 12 summarizes the average frequency and percentage of each means being selected along with the standard deviation and confidence interval values at 95% confidence rate.

Overall, results show that visibility had a higher weight in the discovery of places. Based on the table, at a 95% confidence level, visibility of a place had a 52 ± 9.42% role in how places were discovered by students. The need that a place serves was the second highly selected means through which students had discovered places with a 25± 11.65% role. Finally, Seeing emails and word-of-mouth were the two least selected options among the four.

Table 12: Average weight of discovery means for places in the Union

	Frequency (Number)	Frequency (Percent)	Standard Deviation	Confidence Interval
I have seen it while visiting the Union	7343	52%	9.42%	3.49%
I needed to go there for a specific purpose	3488	25%	11.65%	4.31%
I saw emails/signs/posters	1967	14%	4.69%	1.74%
I heard from friends/social media	1273	9%	4.44%	1.64%
Total	**14,072**	**100%**		

These results show the important role that the visibility of a place has in the discovery of it. Understanding the imperative role of visibility, it becomes important to figure out ways through which we can study and measure the visibility of places in a building.

To answer this question, the results from the building analysis and measurements were used to compare with students' responses from the survey. For this purpose, responses were filtered to reflect only the ones that identified they know a place through visibility and based on that, the percent of people who identified they know a place through visibility was calculated for each place.

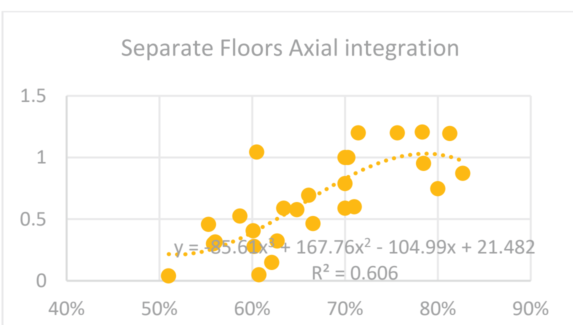
The data was then compared to the results from the visibility measurements of places conducted through various methods (Table6). Table 12 presents the linear correlation results performed in Microsoft Excel.

Table 13: Correlation analysis among discoverability and building measures

	Separate Floors Axial integration	Separate Floors Axial Connectivity	Connected Floors Axial integration	Connected Floors Axial Connectivity	Step Depth from All entrance	VGA Integration	VGA Connectivity	3D Isovist	2D Isovist (Sq ft)
Discover through visibility	**0.76**	**0.77**	0.48	0.64	**-0.66**	0.23	0.27	0.15	0.48

Based on the table, students' ratings of discoverability through visibility for each place correlated highest with separate floors axial integration and connectivity measures. The table also shows a negative correlation between discoverability through visibility and the measure of step depth. The reason is that higher step depth values demonstrate a greater number of steps (changes of direction) to get from an entrance to any place. In other words, unlike all the other measures, a higher step depth means the place is harder to find, while a lower step depth value represents easier access to the place from an entrance.

The correlation scores presented in Table 13 represents a linear correlation coefficient (R) value between students' rating of discoverability through visibility and the results from the different visibility analysis methods. Data was further tested to understand if there are other stronger non-linear relationships. Figure 68 presents the scatter plots of discoverability through visibility data and all the building measures provided earlier. Each plot also displays the R-squared value as well as the equation of the line that best fits on the points.



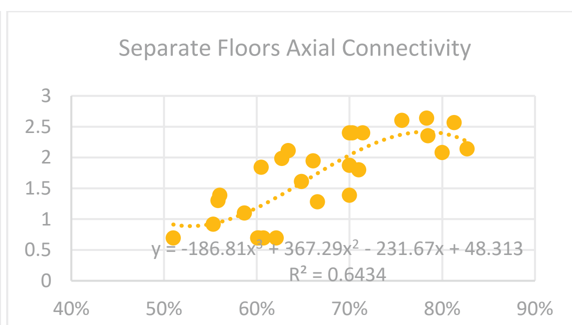


Figure 68: Comparing discoverability through visibility results with building measures

Based on these plots, measures derived from axial line analysis conducted on separate floors of the building could better explain survey results for discoverability by visibility. Among connectivity and integration measures calculated from this method, connectivity seems to correlate slightly better with survey results. Although other methods of calculating connectivity and integration (connected floor axial map and VGA) have some level of positive correlation, yet they are less capable of explaining variations in the discoverability by visibility scores. Discoverability by visibility also seems to have little correlation with 2D and 3D isovist measures of each place.

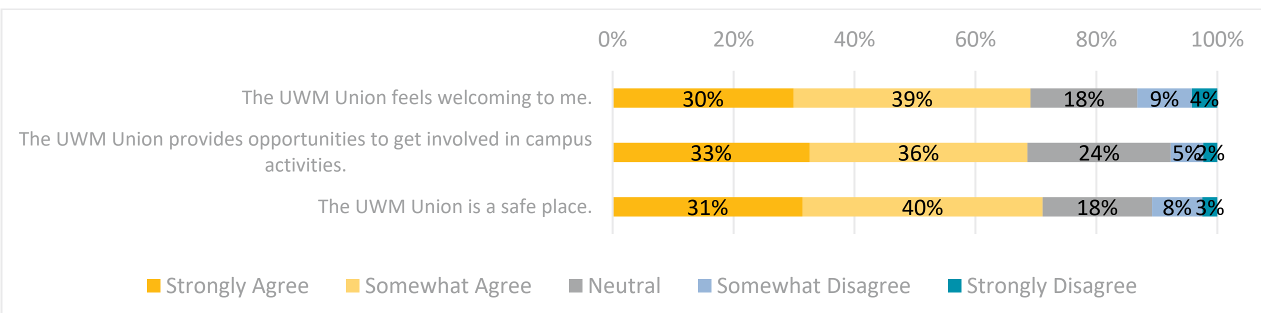
Another measure that seems to correlate highly with survey results was the average step depth score from all entrances. This is an interesting finding which explains the relationship between where places are concerning the floor entrances and survey results on discoverability through visibility. So, unlike the measures of connectivity, integration, and isovist, which are merely calculated based on the plan configuration and are independent from the building entrances, step depth measures places based on where people enter and exit the building and is, therefore, closer to the actual way people use the building.

Based on these results, a new measure was developed which was calculated by multiplying the results from each of the methods of visibility analysis for each place by the inverse of step depth value of those places. The idea was to bring the values in the context of the existing building by assigning a weight for where places are located in relation to the floor entrances. The results, as presented in Figure 69, showed this could predict a slightly higher percentage of survey responses as the new R-squared values increased for all measures. Regarding the separate floor axial connectivity measure, the R-squared values increased from 0.64 (Figure 68) to 0.72 (Figure 69).

Figure 69: Comparing discoverability through visibility results with building measures multiplied by Step Depth

4.1.4. Inclusion and Safety

To understand students' perception of the UWM Union, the survey presented three statements to respondents and asked them to indicate how much they agree or disagree with each statement. These statements were centered around issues of the Union being a welcoming and safe space and the level to which it provides opportunities for students to get involved in campus activities. Responses were recorded on a five-point scale from Strongly Agree (+2) to Strongly Disagree (-2). Figure 70 shows the distribution of responses for each statement based on the level of agreement with the statements. It also shows the overall average score for each statement. Overall, respondents were rather satisfied with the Union and the level to which it is a safe and welcoming space and offers involvement opportunities.



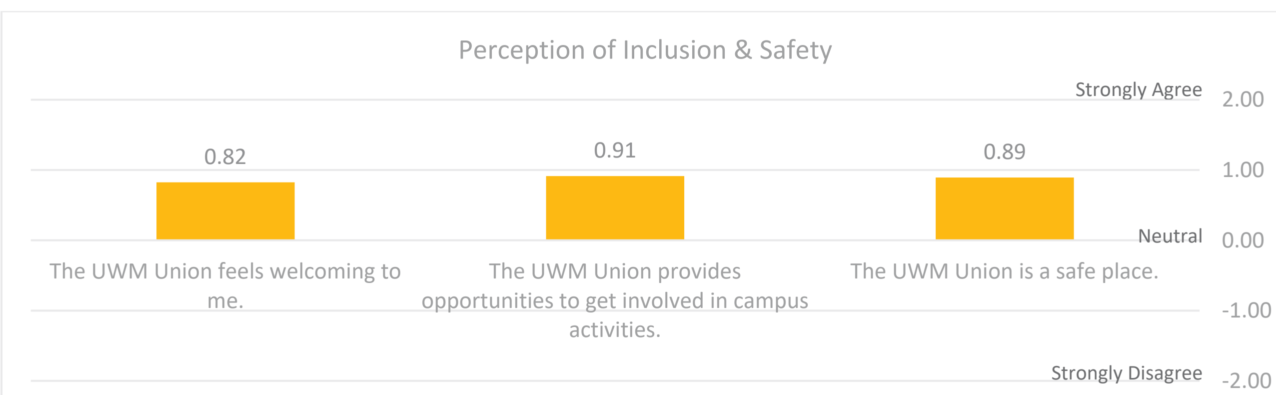


Figure 70: Respondents' perception of the Union building

Figure 70 presents the aggregated results for all respondents. To better understand if students from different groups provided similar or different responses, each of the statements was further studied based on the respondents' breakdown of gender, school, year in school, and race.

The UWM Union feels welcoming to me.

The overall average agreement score for this statement was 0.82 (1= Somewhat agree). To understand any differences in the average score provided by different groups, a Welch's ANOVA test was conducted. The result of this statistical analysis is presented in Table 14. The results showed that there were significant differences between group means, when responses were categorized based on students' year in school ($F(5, 75.52)= 3.83$, $P= 0.004$). To understand which group means are significantly different, a Games-Howell post hoc test was conducted. The post hoc pairwise comparison further revealed that the First-year students (Mean=1.15) perceived the Union to be a welcoming space, significantly higher than Third-year students (Mean= 0.70, $P= 0.04$), Fourth-year students (Mean=0.65, $P= 0.009$) and graduate students (Mean=0.73, $P= 0.03$). This is an interesting finding as it reveals how students in different years at school perceive the Union and how welcoming it is.

The breakdown of responses based on respondents' race also revealed a statistically significant difference between groups ($F(5, 22.55)= 2.90$, $P= 0.03$). The post hoc test showed that the significant difference was specifically between the White and Hispanic/Latino respondents, in a way that the latter perceived the Union to be a significantly more welcoming space compared to white students (Hispanic/Latino=1.28, White=0.78, *P*= 0.008). The responses to the open-ended question in this section of the questionnaire did not help in answering why such a difference existed, therefore what can be speculated is that there may be different resources available to each of these groups which can impact their perception of being welcomed in the Union, or such a difference exists simply due to a cultural effect. In any case, further investigation is required to understand the reason behind this finding.

Based on the results, there was no significant difference in group means based on respondents' gender (F(2, 28.33)=0.02, *P*=0.98) or school (F(10, 92.37)=0.68, *P*= 0.74). In other words, we cannot conclude that the Union may welcome students with different gender, or those from different schools significantly different.

Table 14: Welch's ANOVA results for students' rating of welcoming

		Count	Mean	F	*P*-value
Gender	Gender Variant	11	0.82	0.02	0.98
	Man	179	0.84		
	Woman	311	0.82		
Year in school	**First Year**	84	1.15	3.83	0.004*
	Second Year	81	1.07		
	Third Year	97	0.70		
	Fourth Year	125	0.65		
	Graduate Student	116	0.73		
	Continuing Education	9	0.78		
School	Architecture and Urban Planning	18	1.00	0.68	0.74
	College of Engineering & Applied Sciences	51	0.78		
	College of Health Sciences	31	0.94		
	College of Letters & Science	137	0.78		
	College of Nursing	28	0.79		
	Helen Bader School of Social Welfare	28	0.71		
	Joseph J. Zilber School of Public Health	7	1.00		
	Lubar School of Business	65	0.78		
	Peck School of the Arts	48	1.10		
	School of Education	47	0.74		
	School of Information Studies	17	0.76		
Race	African American/Black	11	0.82	2.90	0.04*
	Asian	44	1.07		
	Hispanic/Latino	43	1.28		
	Multiracial	17	1.06		
	Native American/American Indian/Alaskan Native	4	1.00		
	White	365	0.78		

*significant at 95% confidence level

The UWM Union is a safe place.

Based on Figure 70 the average agreement scores with the Union being a safe place was 0.89. Respondents mentioned the Women's resource center and LGBT resource center as places that make them feel safe because they can find people there who listen to them and provide them with the resources they need. On the other hand, several respondents brought up safety concerns regarding the presence of homeless people, which makes them feel uncomfortable to be in certain areas of the Union or to leave their belongings unattended in the building.

Table 15 presents the results of Welch's ANOVA test on the breakdown of responses based on the four categories of gender, year in school, school, and race.

Table 15: Welch's ANOVA results for students' rating of safety

		Count	Mean	F	*P*-value
Gender	Gender Variant	11	0.45	4.30	0.02*
	Man	**178**	**1.06**		
	Woman	**311**	**0.83**		
Year in school	**First Year**	**84**	**1.14**	2.14	0.07
	Second Year	81	0.95		
	Third Year	95	0.84		
	Fourth Year	**125**	**0.70**		
	Graduate Student	116	0.97		
	Continuing Education	10	0.70		
School	Architecture and Urban Planning	18	1.11	0.84	0.60
	College of Engineering & Applied Sciences	51	0.98		
	College of Health Sciences	31	0.84		
	College of Letters & Science	136	0.84		
	College of Nursing	27	0.67		
	Helen Bader School of Social Welfare	28	0.82		
	Joseph J. Zilber School of Public Health	7	1.00		
	Lubar School of Business	65	0.86		
	Peck School of the Arts	48	1.04		
	School of Education	47	0.96		
	School of Information Studies	17	1.24		
Race	**African American/Black**	**11**	**0.09**	3.36	0.02*
	Asian	45	0.84		
	Hispanic/Latino	**43**	**1.28**		
	Multiracial	16	0.94		

Native American/American Indian/Alaskan Native	4	1.25
White	364	0.91

*significant at 95% confidence level

Welch's ANOVA test revealed a significant difference in the perception of safety at the Union based on respondents' gender (F(2, 27.67)=4.30, *P*=0.02). The Games-Howell post hoc test revealed that on average, male respondents gave a significantly higher score to safety at the Union, compared to female respondents (Man mean=1.06, Woman mean=0.83, *P*=0.05).

Regarding respondents' demographic breakdown based on year in school, although the Welch' ANOVA test did not show a significant difference between groups (F(5, 81.62)=2.14, *P*=0.07), the pairwise comparison in the Games-Howell post hoc test showed that there was a significant difference between the First-year and Fourth-year students in the average score provided (First-year mean=1.14, Fourth-year mean=0.70, *P*=0.02). This is a case that can happen in a statistical analysis where, although the overall ANOVA has a *p*-value greater than the significance level, the post hoc test detects significant differences between group means. This is still a valid result and can be relied on to detect significant differences between group means (Chen, Xu, Tu, Wang, and Niu, 2018).

The test also showed a significant difference in the responses to the question of safety based on respondents' race (F(5, 22.34)=3.36, *P*=0.02). The post hoc test revealed that the significant difference in the responses between the African American/Black students and Hispanic/Latino students, where the latter provided a significantly higher rating regarding safety at the Union building (African American/Black mean=0.09, Hispanic/Latino mean=1.28, *P*=0.008). Again, to understand the reason behind this finding needs further investigation.

As the Table shows, there were no significant differences between group means based on students' year in school (F(5, 81.62)= 4.30, *P*= 0.07) or school they attended (F(10, 93.22)= 0.84, *P*= 0.60).

The UWM Union provides opportunities to get involved in campus activities.

The last statement students were asked was about the role of the Union in providing opportunities for involvement in campus activities. The overall score from all responses to this statement was 0.91. Results were further analyzed to understand if there is a perception that the Union provides more involvement opportunities for any of the demographic categories of gender, year in school, school, or race. The Welch's ANOVA test showed no significant difference in the average response provided to this question based on respondents' gender (F(2, 28.45)=2.52, *P*=0.09), year in school (F(5, 74.93)=1.55, *P*=0.18), school (F(10, 92.60)=0.52, *P*=0.87) or race (F(5, 22.78)=, *P*=0.27). This shows that when comparing to each other, none of the groups under the four categories perceived a significant difference in the way the Union provides opportunities for involvement in campus activities.

Table 16: Welch's ANOVA results for students' rating of involvement opportunities

		Count	Mean	F	*P*-value
Gender	Gender Variant	11	1.27	2.52	0.09
	Man	178	0.83		
	Woman	311	0.98		
Year in school	First Year	84	1.11	1.55	0.18
	Second Year	81	1.00		
	Third Year	97	0.95		

	Fourth Year	124	0.89		
	Graduate Student	116	0.76		
	Continuing Education	9	0.56		
School	Architecture and Urban Planning	18	0.83	0.52	0.87
	College of Engineering & Applied Sciences	51	0.73		
	College of Health Sciences	31	1.00		
	College of Letters & Science	136	0.94		
	College of Nursing	28	0.93		
	Helen Bader School of Social Welfare	28	1.11		
	Joseph J. Zilber School of Public Health	7	1.29		
	Lubar School of Business	65	1.02		
	Peck School of the Arts	48	0.98		
	School of Education	47	0.87		
	School of Information Studies	17	1.00		
Race	African American/Black	11	0.55	1.38	0.27
	Asian	44	1.02		
	Hispanic/Latino	43	1.16		
	Multiracial	17	1.00		
	Native American/American Indian/Alaskan Native	4	1.50		
	White	365	0.94		

*significant at 95% confidence level

The study sought to further understand if the number of places that students are familiar with (from an earlier question in the survey) may have any impact on their rating of involvement opportunities in the Union. To understand this, a T-test analysis was performed between two groups: Those who Strongly/Somewhat agreed with the Union providing involvement opportunities, and those who Strongly/Somewhat disagreed with this statement. The number of places that students indicated they are familiar with was compared between the two categories.

The results of the T-Test analysis showed that at a 95% confidence level, there is a significant difference in the average number of places that students are familiar with between the two groups (P= 0.01). In other words, those who think that the Union provides more involvement opportunities are familiar with significantly more places in the Union, compared to those who think that the Union does not provide involvement opportunities.

Table 17: T-test analysis results for comparing the number for familiar places

	The UWM Union provides opportunities to get involved in campus activities		*P*-Value	t	df
	Strongly/Somewhat Agree	**Strongly/Somewhat disagree**			
Number of places students are familiar with	23.55	20.32	0.01	2.01	45

Besides the Likert type questions, the survey also asked respondents to name any places or programs in the UWM Union that makes them feel welcomed and included. This was an open-ended question that enabled respondents to write their comments in a comment box. A total of 137 responses were recorded for this question. The main keywords from these responses were extracted and are presented in Figure 71 based on their frequencies. The top welcoming and inclusive areas and programs as identified by students as are:

1. Coffeeshops (the Grind, 8^{th} Note and Flour Shop) and Gasthaus, where respondents believed had welcoming spaces and staff where they could sit alone or hang out with other people.
2. Resource centers (Women's resource center, LGBT, MAVRC, Inclusive Excellence Center, CCBLR), which were thought to be safe, friendly and inclusive as people mentioned they could walk in and be listened to by caring and knowledgeable staff and meet like-minded peers. These places were also not well known to students overall. So, for the students who know about them, it seems like they play a pivotal role in their college experience.

3. Student Involvement activities, Student Clubs and Student Organizations, as they provide opportunities to meet other people and get involved through various activities that they plan.
4. Events of different kinds (lectures, welcome events, etc.) and event spaces (like Ballroom, Fireside lounge, or the concourse with event posters)

Other welcoming and inclusive areas that students identified included art activity areas (Arts and Craft center and the Union Art gallery) and Lounges on different levels of the building. The Union Cinema and the Rec Center, which both relate to recreational activities in the Union, were also included by some respondents.

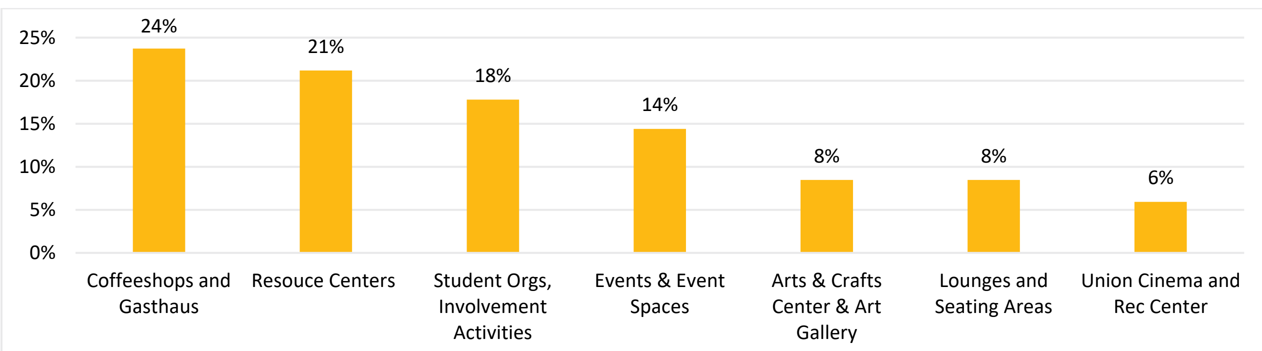


Figure 71*:* Welcoming and Inclusive areas in the Union based on respondents' comments

Figure 72: Gasthaus

Figure 73: Ballroom

Figure 74: Union Art Gallery

Learning about students’ perception of welcoming and inclusive areas in the Union is important in programming those places in the most accessible areas of the building to have the most impact on creating a welcoming and inclusive Union. This underlines the importance of the discoverability of these places in a Union building. In line with this, one student commented:

"I think that the aspects of the union should be promoted more. I learned about things a year into going to UWM that I wish I had known about from the beginning."

By comparing the results of welcoming and inclusive areas identified by students with the results from place familiarity frequency of visit (Figure 75) we can evaluate how each place is functioning to fulfill its role in creating a welcoming and inclusive Union:

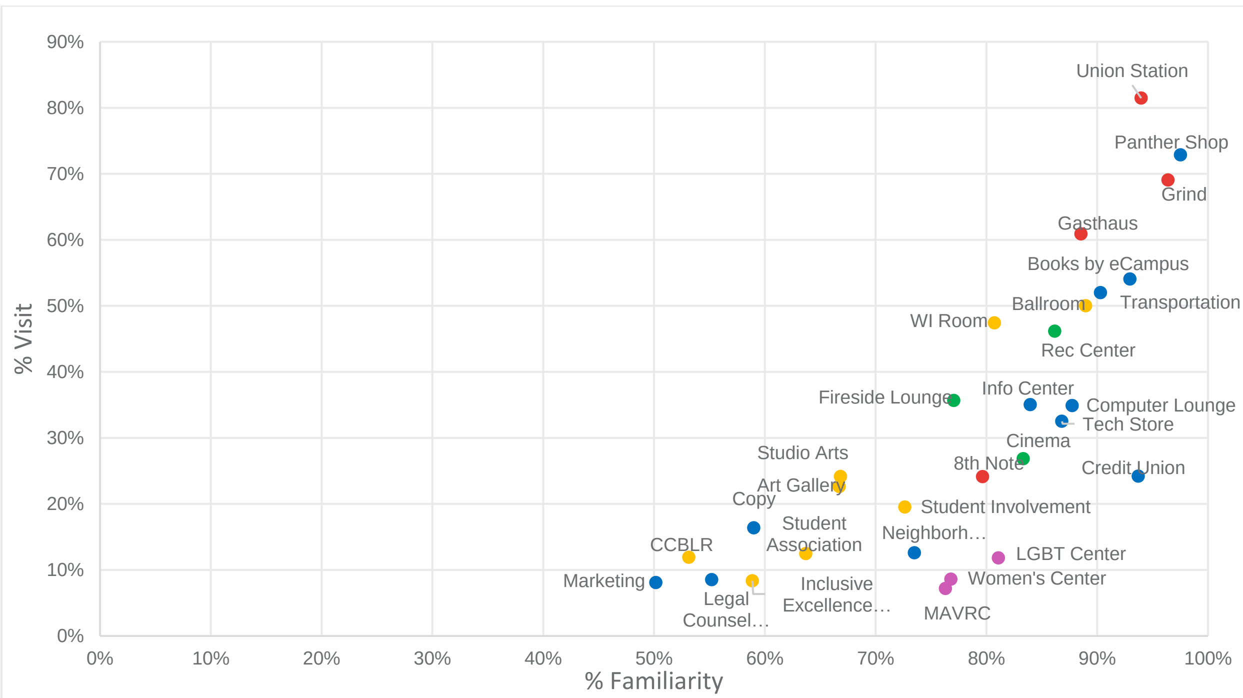


Figure 75: Breakdown of places based on % respondents who had some level of familiarity with the place and have visited at least once

1- Based on the figure, both Gasthaus and Grind Coffee Shop are familiar and highly used by students. On the other hand, although the 8th Note Coffee shop is familiar for most people, it is not as often visited by people as the Grind. This may relate to the design of the place, which does not offer a great deal of visual permeability so people can see what goes inside as they pass by it. This lack of permeability may be the reason for one of the respondents’ comment as they said:

“the 8th note coffee … [is] very exclusive, not many open opportunities for all students to mingle.”

Figure 76: 8th Note Coffee Shop

2- Figure 75 shows resource centers like Women's Center, LGBT Center, MAVRC, Neighborhood housing are familiar for more than 70% of students. The less visit to these places may relate to the need that these places may serve for a specific group of people. Inclusive Excellence Center and Center for Community based Learning (CCBLUR) have lower scores in terms of respondents’ familiarity and frequency of visit.

3- The third important piece in creating welcoming and inclusive environments was Involvement activities, Student Clubs and, Student Organizations (Figure 71). Despite the important role of these places, Figure 75 shows that Student Association Offices and Student Involvement were among the less familiar and visited places in the Union. One factor that may contribute to this may be the location of these places which makes it harder for people to learn about and get more involved with them. Student involvement and Student organization offices are located on the third level of the Union, while Student Association offices are located in a secluded area on the street level of the Union. Table 6 can also present how these areas score low in their visibility analysis.

Figure 77: Student Involvement Lounge on the third level

Figure 78: Student Organization Offices on the third level

4.3. Discussion

This chapter presented the results for the UWM Union building analysis as well as the results from an online survey distributed among UWM students. The chapter started with analyzing and describing the architectural plans of UWM union building based on the established 2D methods and measures, as well as a developed model for measuring 3D isovist. These measures were then compared to the results of the study on if students have discovered different places in the building and how well they are familiar with those places.

This study addresses that different architectural and non-architectural factors can contribute to the discovery of places; however, it focuses on the role of architectural factors and visual accessibility of places to identify how these can promote or hinder place discovery. By controlling for non-architectural factors, the study looked for the analysis method that could best correlate with students experience on discovering places to, therefore, develop a quantifiable definition for discoverability.

The overall familiarity with the Union was quite high with the average respondents having discovered 24 places out of the 29 in the list. Familiarity with places also had a high correlation with students' frequency of visits to those places with a 0.88 correlation coefficient. Knowing about a place and familiarity with it can happen through various means.

Based on students' responses to how they have first come to know a place, visibility of a place was the main reason to discover places with an overall 52% average role among all means of discovery of a place. This emphasizes the importance of a visually accessible and permeable design that facilitates the discovery of places for building users.

There are different methods through which the visibility of a place can be measured and evaluated. This study used the methods of Space Syntax axial line analysis (for both connected and separate floors), VGA and Isovist analysis to derive measures of connectivity, integration, step depth, 2D isovist area, and 3D isovist volume for each place in the Union. To understand which of these measures and methods could best relate to the way students experience the building, a comparison was done between the measures and survey results about the visibility of places. Results showed that among the several methods for analyzing and measuring place visibility, separate floor axial connectivity correlated the highest with students' responses.

Further investigation revealed that step depth of each place (or the number of changes in direction that it takes to get from building entrances to a place), when multiplied by building measures, increased the correlation with the survey results. It is especially important to consider the role of building entrances because of the reported use of the building as a thoroughfare. These measures can, therefore, be used in developing a quantifiable definition for discoverability of places.

Survey results regarding student perception on how welcoming, safe, and inclusive the Union was, showed that students had an average satisfaction with the way the Union was performing with regard to these issues. This type of data helps understand how the Union activities and events are being perceived by different groups of students. It can also be used for making data-driven decisions about where investments are working and where and which groups need more attention.

There were some differences between groups in their perception of the Union. First-year students found the Union to be significantly more welcoming than the Third-year, Fourth-year, and graduate students. This may relate to the freshman orientations, but regardless of that, it is an interesting finding as it reveals the positive attitude that this group has toward the Union. Besides freshmen, Hispanic/Latino students had also indicated a significantly higher perception of the Union being a welcoming place compared to white students.

Regarding safety in the Union building, female respondents provided a significantly lower score compared to male students. African American students also seem to not feel that the Union is a safe place specifically compared to Hispanic/Latino students. The same happened with First-year students versus Fourth-year students where the latter significantly rated lower safety scores compared to the freshman group. Based on responses to the open-ended question, one of the major safety concerns that students have in the Union relates to the presence of homeless people. On the other hand, Women's resource center and LGBT resource center were repeatedly recorded as safe places for students due to their staff and the resources that they provide. This emphasizes the important role of these resource centers in providing for safety in the Union buildings.

Finally, when asked about involvement opportunities on campus, there was no significant difference in the average score that respondents from different demographic groups provided. Interestingly, however, there was a relationship between the number of familiar places that students had identified and their perception about involvement opportunities that the Union provided. In other words, respondents who thought that the Union provided involvement opportunities had identified more familiar places in the Union. The bottom line here is that knowing about more places in the Union building seems to correlate with students' perception of inclusion in the campus environment. On the other hand, as we saw earlier, the visibility of a location can have the most important weight in discovering or knowing about places. Therefore, the more visible can result in more discoverable and more familiarity opportunities, which in turn can lead to a higher perception of inclusion. This can especially be the case for programs in the Union that are used voluntarily like resource centers or student involvement, or student organization offices.

5. CONCLUSION

To encourage users to explore buildings, buildings need to engage in a clear storytelling. This becomes specifically important in complex buildings that offer a variety of services and resources. Building users may rarely get to know all of the resources that are available in them. Therefore, it is important to make sure that the spaces within them *can* be discovered. The more people get to learn about what the building offers, the higher the opportunities for engagement and utilizing the resources available to them. In this context, the visual accessibility patterns that the building offers is an important factor in enabling and inviting people to explore and discover different places in a building.

This study sought to define discoverability as a quality imperative for the design of complex buildings. The discoverability of places in a building as defined here refers to the potential of places to be found by building users. Places are discovered if people know about them and know that such places exist in a building. Therefore, discoverability refers to the ease with which a place can be found in a building.

The main difference between discoverability and similar concepts like wayfinding and legibility is that these concepts are centered around people's ability to understand *spatial relationships between places* and developing a clear *cognitive map* of the environment. Also, their focus is on both physical and visual accessibility. Discoverability, on the other hand, focuses on knowing what destinations exist in the building and how easily they can be found. In other words, the focus is not on the spatial relationship between places, but knowledge of individual places themselves. This can happen merely through visual accessibility and does not necessarily need immediate physical access. It is fair to say that discoverability with an emphasis on visual access is a component of architectural legibility.

Another difference from the earlier concepts is this study's approach in providing a quantifiable definition for discoverability in relation to the layout of the building. This quantifiable definition can be used to measure how easily people can discover each location in a building. This study defines discoverability as a product of the inverse of a destination's step depth in a building and its visibility:

Discoverability = Visibility / Depth

There are two major components in this definition: the *depth* of a destination and its *visual access* to other places, both of which are quantifiable elements.

The *depth* of a destination is measured through its step depth value with regard to the building entrances. Step depth is the number of steps (changes of direction) it takes to get from entrance(s) to the destination(s) (Pinelo, Turner, 2010). This value represents how visually deep destinations are located with regard to the building entrance. The definition of discoverability uses the inverse value of step depth because the deeper places are located farther from the entrances. If a destination is too deep in the building, it may hinder people from discovering it. It will be more of a hidden space rather than a discoverable one. Of course, any deep space has the potential for discovery, but the deeper it gets, the lower the potential becomes.

The definition of discoverability also emphasizes *visual access* to places. As reviewed in this study, there are different methods one can use to describe the visual attributes of places, including space syntax axial line, visibility graph analysis (VGA) and two-dimensional isovist analysis (Hillier & Hanson, 198; Turner et al., 2001; Benedikt, 1979). Besides these, the study also presented a new technique for measuring the three-dimensional visual field as a methodological contribution to fill a gap in visual analysis methodology. To understand which of these methods could best relate to the experience of the users of space, the study compared measures derived from different methods of visual analysis of space with results from an online survey. This combination allowed for the merging of quantitative spatial analysis with personal experiences and perceptions of students. The study found that among the different methods, space syntax axial line analysis best correlated with students' responses on place discovery. As the results showed, multiplying axial connectivity by the inverse of step depth values, showed a better fit for the purpose of predicting discoverability within a complex building. However, using axial line analysis in the definition of discoverability does not suggest that other methods of visual analysis are less valuable. Each of the methods has certain advantages and disadvantages.

This definition presented here can be used for identifying the most and least discoverable areas in a building. It can also be utilized in the design phase for programming of places in a building, or for manipulation of visual accessibility of spaces to form various visibility compositions.

Although the focus of this research was on architectural factors, non-architectural factors can also have a role in discovering places. This study found from the online survey that the visibility of places is the main reason for places to be discovered, while the second reason for discovering a place was the function of a place and the need it serves. The practical implication of this finding suggests that areas discovered based on need could be moved to less visible areas. This would free up more visible spaces for other activities like student involvement and student association offices whose discovery may benefit from greater visibility.

While the concept of discoverability and how it relates to the building layout can apply to any complex building, this study focused on student union buildings due to their important role in influencing students' experiences on college campuses. By providing a welcoming and inclusive environment, union buildings can provide opportunities for student engagement in campus activities which can, in turn, result in strengthening the sense of community on campus and among students. The importance of this issue is not only for an enriched experience of students but also for increasing the retention rate and decreasing student departure from universities (Strange and Banning, 2015).

This research tried to address how discoverability of places can impact issues of involvement and inclusion in a Union building. The study found that there is a relationship between the number of places that students know about, with their perception of involvement opportunities in campus activities in a way that students who knew more places in the Union, also thought that the Union provides more opportunities for involvement in campus activities. This again confirms the importance of discoverability of places and its impact on students' perception of inclusion.

It is important to note that the findings of the current research are based on the study of a single case of a union building. Therefore, the investigation here is more exploratory. As Yin (2014) states, although single case studies can yield invaluable understandings, a multiple case study design is likely to yield more insights than a single case study design. Another limitation of this study was the low response rate from students. Although the survey was sent out to nearly 10,000 students, there were only 630 completed responses. It is fair to say that a higher response rate could result in more reliable findings.

This study relied on the names of places to ask about students' familiarity with those. One limitation of this approach is that some respondents may know about a place but are not familiar with its name as provided in the questionnaire. Finally, to keep the survey short, the number of places that were included in the survey had to be limited. Therefore, although the questionnaire tried to include as many places as possible, not all the places in the Union could be included in the survey.

Future research may consider these limitations and examine further cases of student union buildings. Another area for a future study could be to analyze other complex buildings like workplaces or museums to further explore the concept of discoverability in relation to the building layout in other place types.

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APPENDIX

UWM Student Union Building Survey

The purpose of this survey is to understand how students at the University of Wisconsin-Milwaukee use the UWM Student Union Building. In particular, this survey is designed to collect data on how familiar students are with the building and the different resources and activity spaces that it offers. The entire survey should take about 10 to 15 minutes to complete.

Confidentiality: Your answers will remain confidential. Only the study team will have access to the raw data collected. Data will be retained in an encrypted format by researchers conducting this survey, for up to 10 years.

Voluntary Participation: Your participation in this survey is voluntary. You may choose to not answer any of the questions or withdraw from this survey at any time without penalty. Your decision will not change your present or future relationship with UW-Milwaukee.

Who do I contact for questions about the study: For more information about the study or study procedures, please contact UWM Institutional Review Board office at irbinfo@uwm.edu or 414-229-3182, or Mahshid Jalalian, Ph.D. candidate in architecture at jalalia2@uwm.edu.

Research Subject's Consent to Participate: By completing this survey, you are indicating that you have read this information, you are age 18 or older, and that you voluntarily agree to participate. To participate, you might not be a regular visitor to the UWM Union, but you should be at least somewhat familiar with the building.

To proceed, click on the arrow at the lower right.

Thank you!

GENERAL USE & FAMILIARITY

How familiar are you with the UWM Union building?

- ☐ Very familiar
- ☐ Somewhat familiar
- ☐ Neutral
- ☐ Somewhat unfamiliar
- ☐ Very unfamiliar

How often do you visit the Union building?

- ☐ Rarely or never
- ☐ Once or twice a semester
- ☐ Once or twice a month
- ☐ Once or twice a week
- ☐ 3+ times a week

How much time do you spend in the union during a typical visit?

- ☐ Less than 30 minutes
- ☐ 30 minutes to 1 hour
- ☐ 1 to 2 hours
- ☐ 2 to 4 hours
- ☐ More than 4 hours

FAMILIARITY

Please answer the following questions about different places in the UWM Union building.

	How familiar are you with this place?				How often do you visit this place?			
	I did not know it exists!	Slightly	Somewhat	Very	Never	1-2 times a semester	1-2 times a week	3+ times a week
Inclusive Excellence Center	○	○	○	○	○	○	○	○
Grind Coffee shop	○	○	○	○	○	○	○	○
Neighborhood Housing	○	○	○	○	○	○	○	○
Ballroom	○	○	○	○	○	○	○	○
The Union Station (Food on Kenwood Street Level)	○	○	○	○	○	○	○	○
Studio Arts & Craft Center	○	○	○	○	○	○	○	○
UW Credit Union	○	○	○	○	○	○	○	○
Alumni Fireside Lounge	○	○	○	○	○	○	○	○
Computer Lounge	○	○	○	○	○	○	○	○
8th Note Coffee House	○	○	○	○	○	○	○	○
	I did not know it exists!	Slightly	Somewhat	Very	Never	1-2 times a semester	1-2 times a week	3+ times a week
Student Involvement	○	○	○	○	○	○	○	○
Union Information Center	○	○	○	○	○	○	○	○
Books by eCampus	○	○	○	○	○	○	○	○
Legal Counseling	○	○	○	○	○	○	○	○
Copy Center	○	○	○	○	○	○	○	○
Center for Community Based Learning, Leadership, and Research (CCBLR)	○	○	○	○	○	○	○	○
Student Association Offices	○	○	○	○	○	○	○	○
Union Rec Center (Bowling & Table Tennis)	○	○	○	○	○	○	○	○
Women's Resource Center	○	○	○	○	○	○	○	○
Union Art Gallery	○	○	○	○	○	○	○	○
	I did not know it exists!	Slightly	Somewhat	Very	Never	1-2 times a semester	1-2 times a week	3+ times a week
Gasthaus	○	○	○	○	○	○	○	○
Marketing Services	○	○	○	○	○	○	○	○
Military and Veteran Resource Center	○	○	○	○	○	○	○	○
Transportation Services	○	○	○	○	○	○	○	○
Wisconsin Room	○	○	○	○	○	○	○	○
UWM Tech Store	○	○	○	○	○	○	○	○
Union Cinema	○	○	○	○	○	○	○	○
LGBT Resource Center	○	○	○	○	○	○	○	○
Panther Shop	○	○	○	○	○	○	○	○

Discoverability

SELECT ALL THAT APPLY: I know about this place because ...

	I have seen it while visiting the Union	I needed to go there for a specific purpose	I heard from friends/social media	I saw emails/signs/posters	If other, please explain
Union Art Gallery	☐	☐	☐	☐	
Gasthaus	☐	☐	☐	☐	
The Union Station (Food on Kenwood Street Level)	☐	☐	☐	☐	
Panther Shop	☐	☐	☐	☐	
Copy Center	☐	☐	☐	☐	
UW Credit Union	☐	☐	☐	☐	
Center for Community Based Learning, Leadership, and Research (CCBLR)	☐	☐	☐	☐	
Student Involvement	☐	☐	☐	☐	
Inclusive Excellence Center	☐	☐	☐	☐	
Grind Coffee shop	☐	☐	☐	☐	
	I have seen it while visiting the Union	I needed to go there for a specific purpose	I heard from friends/social media	I saw emails/signs/posters	If other, please explain
Union Cinema	☐	☐	☐	☐	
Ballroom	☐	☐	☐	☐	
Marketing Services	☐	☐	☐	☐	
Neighborhood Housing	☐	☐	☐	☐	
Women's Resource Center	☐	☐	☐	☐	
Union Information Center	☐	☐	☐	☐	
Studio Arts & Craft Center	☐	☐	☐	☐	
LGBT Resource Center	☐	☐	☐	☐	
Union Rec Center (Bowling & Table Tennis)	☐	☐	☐	☐	
Student Association Offices	☐	☐	☐	☐	
	I have seen it while visiting the Union	I needed to go there for a specific purpose	I heard from friends/social media	I saw emails/signs/posters	If other, please explain
Alumni Fireside Lounge	☐	☐	☐	☐	
Legal Counseling	☐	☐	☐	☐	
Books by eCampus	☐	☐	☐	☐	

Military and Veteran Resource Center	☐	☐	☐	☐	
Transportation Services	☐	☐	☐	☐	
UWM Tech Store	☐	☐	☐	☐	
Wisconsin Room	☐	☐	☐	☐	
8th Note Coffee House	☐	☐	☐	☐	
Computer Lounge	☐	☐	☐	☐	

PURPOSE & DESTINATIONS

I go to the UWM Union to ... (select all that apply)

- ☐ Eat or drink
- ☐ Study
- ☐ Hang out with friends
- ☐ Meet new people
- ☐ Rest, relax or recreate
- ☐ Spend time between classes
- ☐ Attend events
- ☐ Pass through the building
- ☐ Other:

Name your top three regular destinations in the UWM Union building:

INCLUSION

How much do you agree or disagree with the following statements about UWM Union?

	Strongly agree	Somewhat agree	Neutral	Somewhat disagree	Strongly disagree
The UWM Union feels welcoming to me.	○	○	○	○	○
The UWM Union offers activities and experiences that interest me.	○	○	○	○	○
The UWM Union provides opportunities to get involved in campus activities.	○	○	○	○	○
The UWM Union is a safe place.	○	○	○	○	○

Are there any places or programs in the UWM Union that makes you feel welcomed and included? If yes, please identify and explain why.

TELL US ABOUT YOU

How old are you?

Gender

- ☐ Woman
- ☐ Man
- ☐ Transgender
- ☐ Gender variant/ non-conforming
- ☐ Prefer not to answer

Which best describes your enrollment year at UW-Milwaukee?

- ☐ First Year
- ☐ Second Year
- ☐ Third Year
- ☐ Fourth Year-Plus
- ☐ Graduate Student
- ☐ Continuing Education

Select your school

Race/Ethnicity

- ☐ African American/Black
- ☐ Asian
- ☐ Hawaiian/Pacific Islander
- ☐ Hispanic/Latino
- ☐ Multiracial
- ☐ Native American/American Indian/Alaskan Native
- ☐ White
- ☐ Prefer not to answer

Are you a ... (select all that apply)

- ☐ Veteran
- ☐ International student
- ☐ Member of student organization
- ☐ Person with a disability

☐ Fraternity or sorority member
☐ Member of intercollegiate or club sports
☐ Member of the LGBT community

Which of the following describes your current living situation?

☐ Live on campus
☐ Live off-campus

CURRICULUM VITAE

Mahshid Jalalianhosseini
Jalalia2@uwm.edu

EDUCATION

Sep 2015 – present	**PhD in Architecture – Environmental Design Research** University of Wisconsin-Milwaukee, GPA: 3.98/4
Sep 2016 – Dec 2017	**GIS Certificate** University of Wisconsin-Milwaukee, GPA: 4/4
Sep 2011 – Jan 2014	**M.A. in Urban Design** Tarbiat Modares University. Tehran, Iran. GPA: 3.84/4
Sep 2007 – Sep 2011	**B.Sc. in Urban Planning** Ferdowsi University. Mashhad, Iran. GPA: 3.53/4

EXPERIENCES

Design Workshop Denver, CO
Intern Sep. 2019- May 2020

- ✓ Conducted site analyses using ArcGIS and Rhino-Grasshopper
- ✓ Prepared project deliverables, schematic plans, 3D visualizations, design drawings, site models, using Sketchup, AutoCAD, and hand drawings
- ✓ Conducted project research
- ✓ Contributed to marketing efforts through proposals, internal and external publications

Hammel, Green and Abrahamson (HGA) Milwaukee, WI
Research Intern Sep. 2018- May 2019

Research on healthcare environment:
- ✓ Wrote a research proposal
- ✓ Designed staff and patient satisfaction questionnaire
- ✓ Conducted time and motion study and staff shadowing
- ✓ Conducted visual analysis of research site using Rhino-Grasshopper
- ✓ Analyzed data using Microsoft Excel
- ✓ Published and presented the results

Research on workplace environment:
- ✓ Visual and spatial analysis of architectural layouts based on Space Syntax theory

Community Design Solutions (CDS) UW-Milwaukee
Design Assistant May 2017- Aug 2018

- ✓ Developed conceptual plans and architectural renderings
- ✓ Provided demographic maps using GIS
- ✓ Attended client meetings and focus group meetings

School of Architecture and Urban Planning UW-Milwaukee
Teaching Assistant Fall 2015- Spring 2018

- ✓ ARCH 302: Architecture and Human Behavior
- ✓ ARCH 581: Law & Professional Practice in Architecture
- ✓ URBPLAN 791: Introduction to Urban Geographic Information Systems for Planning

Pre-Urban Planners (PUPS) Program UW-Milwaukee
Instructor Summer 2017

Campus Capital Framework UW- Milwaukee
Project Assistant Summer 2017

PRESENTATIONS

- *Evaluating and Comparing Staff Communication Patterns in Two Cancer Infusion Centers,* Healthcare Research and Education Conference, Stanford, CA, June 2019.
- *Spatial Analysis of Building Indoor Environments Using 3D Isovist*, EDRA 50 Conference, Brooklyn, NY, May 2019.
- *Infusing Research into Design: A study on the Layouts of Cancer Infusion Centers*, Presentation to all HGA offices, Milwaukee, WI, May 2019.
- *Unveiling Spatial Relationships: How spatial characteristics shape awareness and use patterns in Student Union Buildings*, EDRA 49 Conference, Oklahoma City, OK, June 2018.
- *College Unions and First-Year Students: Results from an Online Mapping Survey*. ACUI Region V conference, October 2017.
- *Revitalizing a Plaza: A Study on a Historically Significant Public space in Tehran*, USP Student Research Forum, University of Wisconsin- Milwaukee, March 2017.
- *Public Art, Public Space, and People*. Anthropology Colloquium, University of Wisconsin-Milwaukee, March 2016.
- *The Role of Social Spaces in Innovation Districts*, EDRA 47 Conference, Raleigh- North Carolina, May 2016.
- *The Role of Urban Design in Upgrading Cross-Cultural communications in urban spaces*. EDRA 47 Conference, Raleigh- North Carolina, May 2016.
- *The Student Union Buildings in the United States*. Tarbiat Modares, May 2015.

- *A Review on the Correlation of Internal and External Public Spaces: Comparison of Traditional and Contemporary Urban Design Principle; Case Study: Paradis new town*, The First National Conference of New Ideas and Technologies in Architecture, March 2012, Tabriz, Iran.

PUBLICATIONS

- *The Impact of Layout on Workflow and Satisfactions in Two Cancer Infusion Centers: A Case Study on Staff and Patients,* Health Environments Research & Design Journal (HERD), November 2019. https://doi.org/10.1177/1937586719888221
- *Learning from European Capitals of Culture Program in developing urban tourism*, Journal of civil engineering and urbanism, Vol. 4, 2014
- *A review on the book: Theoretical Analysis of the contemporary urban design*, The Book of Art journal, No. 165, Tehran, Iran.
- *The Role of Socio-Cultural Components on the Performance of Mosques in Urban Neighborhoods Case Study: A Comparative Study of Three Districts of Tehran*. International Journal of Architecture and Urban Development, Vol.4, No.2, Spring 2014, Tehran, Iran

HONORS AND AWARDS

- Certificate of Research Excellence, Environmental Design Research Association (2020)
- UW-Milwaukee Distinguished Graduate Student Fellowship (2018-2019)
- Design Council Scholarship, School of Architecture and Urban Planning at UW-Milwaukee (2019)
- Environmental Design Research Association Conference Scholarship (2016, 2020)

WORKSHOPS & CERTIFICATES

- University Innovation Fellow, NSF funded Program of Stanford d.school, Oct 2016
- NSF Innovation Corps Summer Program, Focus: Customer Discovery, Aug 2016

SOFTWARE SKILLS

Adobe Suite (Photoshop, Illustrator, InDesign), AutoCAD, ArcGIS, Revit, Grasshopper, SPSS, Google Sketch UP, Depthmap (Space Syntax Analysis)