BUILDING RECOGNIZABILITY IN URBAN ENVIRONMENTS

by

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One of the main scopes of geospatial information sciences is providing the necessary tools and techniques to better understand the interaction between humans and their surrounding environments. As the recognition of buildings in an environment leads to the interaction between human and their surroundings, it can be also studied through the lens of geospatial information sciences. This paper uses a quantitative survey and regression analysis to demonstrate a quantitative approach to predict factors that influence visual recognition or recognizability of buildings in an urban environment. Distance away from buildings, presence of vegetation, frequent downtown visits, and physical forms of buildings contribute significantly to the visual recognition of urban buildings. The result can be beneficial to urban planners, architects, city planners, urban geographers, and city tourism board for better integrating vegetation and buildings in a cityscape. The ultimate goal of understanding people's visual recognition and perception of urban objects is to raise inhabitant's satisfaction, capture their attention, and make strong impressions towards the city.

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CHAPTER 1

INTRODUCTION

Visibility and viewshed analyses have been applied to many disciplines in an attempt to identify and solve spatial problems regarding which objects can or cannot be seen from observation points across natural terrain or a built environment. With the availability of the Geographic Information System (GIS) toolkits, visibility studies have become increasingly accessible in different disciplines, such as architecture (Turner et al., 2001), archaeology (Fisher et al., 1997; Paliou, 2011), urban planning (Danese, 2009), human behavior, (Pearson et al., 2014) and forestry (Dean et al., 1997).

The current approaches used in visibility and viewshed studies heavily focus on the accuracy of viewshed delineation techniques. The accuracy of these techniques can be affected by different sources of error. Riggs and Dean (2007) suggest that errors from digital elevation models (DEMs), the limited spatial resolution of DEMs, and differing algorithms used by different GIS packages may have possibly contributed to the inaccuracy and non-repeatability in viewshed analysis. They tested their ideas by comparing predicted viewsheds, which were produced by a variety of DEMs and algorithms, to survey DEMs in a number of natural mountainous areas. The same DEM and GIS-based viewshed analysis techniques evaluated in natural areas by Riggs and Dean are also used to delineate visibility in rural environments (Floriani & Magillo, 2003). Little research exists in the evaluation of the accuracy of these techniques when they are applied to an urban environment. A lack of studies concerning how these techniques empirically reflect actual human perception and recognition toward urban environments can be observed.

In addition to the concepts of visibility and viewshed, one of the fundamental concepts explaining an individual's perception and navigation across space in an urban environment is their ability to identify and recognize surrounding urban objects. Lynch (1960) suggests that structuring and identifying the environment is an important trait shared by all mobile animals and man. As a majority of the previous research heavily focuses on the visibility and viewshed delineation, little research exists regarding the expansion of the scope of studying how an urban object is perceived spatially with the investigation of recognizability of urban objects. It can be argued that the recognizability of urban objects such as buildings can be at least perceived as an important element of way-finding, similar to visibility (Lynch, 1960). Lynch asserts the strategic link in the process of way-finding is what he considers as the *environmental image*, which indicates the generalized mental picture of the exterior physical world held by a person. In a cluttered environment, permeated with innumerable high-rise buildings and skyscrapers, a person may use recognizable buildings as landmarks for spatial and navigational references. Numerous buildings can be seen from any particular vantage point within an urban area, but not all of them are recognizable—many are nondescript and could be confused with another. The recognizability of a building is a function of the surrounding topography, characteristics of the structure, the building's architectural design, and personal experience. The latter is in a realm of psychology and human behavior and does not serve as the primary focus of this research.

Echoing Lynch's ideas in the 60's, cities today are concerned about their "image" as a tourist destination (Heath et al., 2000). Heath et al. (2000) stated that tourist publications, postcards, souvenirs, and shows on television indicate that the form of the urban skyline is an extremely important component of the city's image. Investigating how the spatial configuration of a city creates this kind of image for both inhabitants and tourists is vital. Buildings are anchors in many urban realms, and, therefore, their unique recognition and visualization contribute to a city's visual signature. While the spatial configuration of a modern city in the 21st century contains more trees and parks than before, the visual signature of a city does not just rely on the silhouette of skylines. Vegetation can significantly complicate the creation of such visual images, as vegetation may block critical parts of buildings; hence, recognition and visualization of building structures is reduced. Urban planners, landscape designers, and geographers may be able to preserve the image of a city by scrutinizing the attributes of the recognizability of urban buildings. In simple terms, they can ensure that buildings, especially the iconic ones, are clearly recognized and visualized from various distances without hindering the view of vegetation. As a result, it is vital to understand how buildings can be recognized in such a complex urban environment.

Again, despite a considerable number of scholarly works devoted to visibility analysis (Bartie et al., 2011; Yin et al., 2012; Fisher et al., 1997), as yet no research the author is aware of has addressed recognizability of urban buildings from the perspective of geospatial information science. This dissertation offers a preliminary research of the subject of the recognizability of spatial objects in a geospatial context. The result of this paper can be applied in the areas of the perception of landscape, cities' image creation, visual quality assessment, urban planning, building design, and spatial configuration of a city.

By offering methods to better understand and quantify recognizability of spatial objects in urban environment, this research aims to investigate the spatial relationship between the observer, obscuring vegetation, and the targets (buildings) and how this relationship influences one aspect of the recognizability of the targets in an urban setting.

The research presented here specifically attempts to provide answers to the following questions:

1. Can statistical techniques be used to understand how buildings are recognized by inhabitants in an urban environment?

2. How can the "recognizability" of buildings be defined and quantified from a geospatial perspective?

3. What are the factors that may potentially influence and predict the recognizability of buildings in an urban environment?

    a. How does the viewing distance and vegetation between an observation point and the target building affect the recognizability of the target building?

    b. Do the socio-demographic characteristics of inhabitants impact the recognizability of buildings?

4. What are the implications of investigating factors of the recognizability of buildings in an urban environment?

This study attempts to demonstrate a quantitative approach to predict the potential attributes that influence the recognizability of buildings in New York City. A quantitative survey is conducted to better understand how distance, socio-demographic factors, and vegetation influence the recognizability of buildings within the study area. To further analyze them statistically, the results of the survey are inputted into regression models. The goal of this research is not to develop a comprehensive and exhaustive model of predicting recognizability. Instead, this paper is a preliminary exploration that attempts to investigate factors of recognizability and suggests how they might be developed and tested through various approaches from a statistical and spatial perspective.

CHAPTER 2

LITERATURE REVIEW

One of the main scopes of geospatial information sciences is providing the necessary tools and techniques to better understand the interaction between humans and their surrounding environments. Lynch (1960) stresses that structuring and identifying the environment is an important ability that is shared by all mobile animals and humans. The need to recognize and pattern our surroundings is equally vital (Lynch, 1960). Human perception toward landscape features has long roots in the realm of geography (Mark et al., 1999; Suleiman et al., 2011; Swetnam et al., 2016; Pardo-García et al., 2017), landscape perception (Sadalla et al., 1980; Zube et al., 1982; Heath & Smith, 2000), urban planning (Daniel, 2001; Bruce Hull et al., 1989; Downes et al., 2015), and architectural studies (Appleyard, 1969; Chang et al., 2018). As the recognition of objects in an environment leads to the interaction between humans and their surroundings, it can be also studied through the lens of geospatial information sciences, which encompasses one of the main scopes of this research.

Human interactions with their surroundings are profoundly complex in a cityscape or an urban environment. A three-dimensional (3D) approach is able to ratify and capture the multi-dimensional reality of how human beings recognize and perceive their surroundings. Urban landscape elements, such as the topological relations between spatial objects, spatial configuration of the city, and visual observation of spatial objects, create the image of a city (Lynch, 1960; Appleyard, 1969; Heath & Smith, 2000). The image provides city planners, designers, and officials a reference to better construct the urban form of this city and improve environmental quality or aesthetics. Steinitz (1967) suggests that they could also coordinate form, visibility, and action with community significance to create a more meaningful city.

The topological relations between spatial objects are widely studied in the field of city model creation (Brenner et al., 2001; Frueh et al., 2004; Shibasaki, 1992), however, these studies overlook the obstruction of vegetation during the process of model creation. The presence of vegetation can also serve as a major obstacle in conventional isovist and visibility studies. Vegetation can become one of the potential factors that influence the recognizability of urban buildings. The literature review below attempts to investigate how previous researches have failed in recognizing the power of vegetation in diminishing one's ability to recognize the target object.

After all, it is necessary to differentiate "seeing the object" from "recognizing the object." This difference is particularly influential in urban studies. As the previous scholarly works heavily relied on the studies of visibility (Turner et al., 2001; Yang et al., 2007; Yin et al., 2012), recognizability of urban objects can help better to construct the form of a cityscape by city planners and officials, where it mimics the reality of how humans perceive the city (Appleyard, 1969; Zube et al., 1982). Appleyard (1969) in his early study mentioned that planners and architects will possess a powerful design tool if one can predict how well the buildings and structures of the city known. To do this, it is vital to study why buildings are known by discovering the attributes of buildings and structures that capture the attention of the inhabitants of the city.

Understanding how buildings are recognized is equally important in the visualization of landscape on ex ante photography during the planning and design phases of landscape architecture projects (Downes et al., 2015). Different depictions of urban elements on an ex ante photo can impact the accuracy, representativeness, visual clarity, interest, legitimacy, and access to visual information for a professional landscape or architectural project (Downes et al., 2015). Downes et al. (2015) attempted comparing the visualization of different urban elements, such as street lights, vegetation, street furniture, built structures on ex-ante photographs, and ex-post photographs of architectural and landscape projects. Existing trees and background shrubs are often omitted in these photographs to improve the view of proposed buildings. In fact, the presence of trees and shrubs may add positive and appealing visual effects on the ex-ante and ex-post photographs of architectural projects. It is thus necessary to include trees and shrubs in these photographs to achieve a genuine background. One of the critical solutions to this dilemma is to understand the spatial relationship and the arrangement between surrounding trees and buildings to create an unhindered view of the building development in the ex-ante photographs. The following questions can be raised regarding this issue: 1) How are buildings and structures recognized? 2) Which part/parts of the building should not be blocked by vegetation in order to communicate and highlight the iconic feature of the building under development?

2.1 GIS approaches in investigating relationship between spatial objects in urban environments

As modern living environments have become more sophisticated with the webs of improved and complex infrastructure, the ability of traditional 2D or 2.5D cartographic tools to show the full scope of spatial reality is limited. Traditional GIS analyses are 2D or 2.5D (Yu, 2006; Amhar et al., 1998; Haala et al., 1997). Researchers suggest that 2D or 2.5D GIS approaches may not be able to adequately provide answers to some geographical questions in various disciplines, including emergency response (Kwan & Lee, 2004), urban design (Yang et al., 2007), and criminology (Wolff, 2009).

On the other hand, Roland (2000) explained two reasons behind not using a 3D model for geographical representation or analysis: first, technical considerations, such as the availability of data and the lack of adequate data structure, may inhibit the use of a 3D model; the second reason is conceptual. If a geographical phenomenon or event can be adequately investigated and explained with a 2D approach, then 3D modeling is not necessary. However, with the increasing availability and accuracy of spatial data nowadays, 3D models have greatly contributed to the realm of geospatial information science to support data analysis and data visualization processes of various urban applications such as urban studies (Deng et al., 2016; Kwan & Lee, 2006; Hijazi et al., 2011).

3D GIS also extends the value and application of the existing 2D GIS data (ESRI 2014). One of the obvious advantages of utilizing the existing 2D spatial data with 3D GIS is that it helps depict the vertical information on more intuitive maps. Roland (2000) claimed that when a geographical phenomenon is sufficiently explained with the use of 2D GIS, 3D GIS is not necessary. There is still considerable disagreement with regard to this argument, as 2D GIS may not serve as the best tool to fully explain geographical phenomena with complex scenes, extended data structure, and multidimensional attributes. Geographical phenomena with urban applications often fall in this category. For example, the spatial data of trees and buildings in an urban environment always comprises “height” components or the *z* factor. Modeling the urban environment with 3D GIS can incorporate the height factor of datasets to develop a more complex geospatial analysis of urban features. The goal is to enhance the probability of making more satisfactory decisions. For instance, a better understanding of the sun exposure, height of surrounding vegetation, and effects of shadow to nearby buildings can facilitate a better approach with 3D GIS to construct and locate a “green” building in order to maximize energy efficiency.

While this research attempts to investigate how urban buildings are obstructed by trees and hence influenced recognizability, a 3D approach for identifying the relationship between trees and nearby buildings is necessary. Pilouk (1996) suggests the core reason behind using a 3D GIS model in urban studies is that it contains knowledge about reality. Therefore, it is necessary to consider all types of real-world objects that this model can represent. He further explains the need for a 3D data model in understanding the 3D topological space of spatial objects. Topological relations between 3D urban objects such as urban buildings differ from the example above. Shibasaki (1992) suggests a geographic object such as a building in an urban space consists of planar polygons and edges. It is very necessary to efficiently establish 3D spatial databases of urban objects by establishing topological relations between these polygons and edges. However, in a complex environment such as New York City, topological relations between buildings are complicated and heavily depend on the architectural design as well as other nearby urban objects, such as vegetation and overpasses. The core topological relations between urban buildings of this research are illustrated in Figures 2-1, 2-2, and 2-3. Urban buildings such as multi-stories residential units or skyscrapers constitute the streetscape in metropolitan areas. Two buildings can be separated by open spaces in between, and there is no connection or a shared-wall between these two buildings.

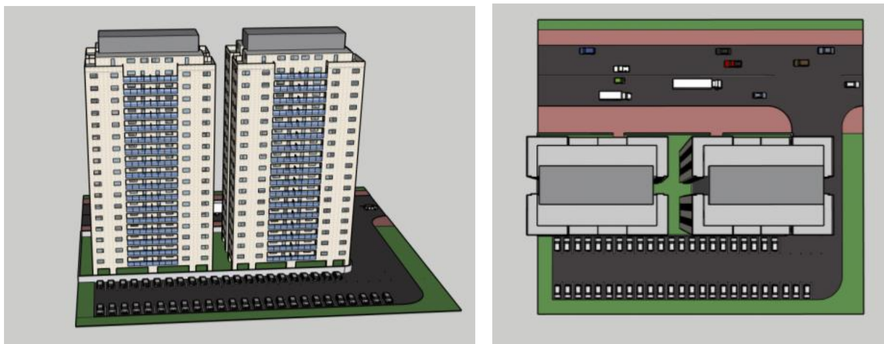

Figure 2-1(a) and (b). The first type of topological relation between buildings: two buildings are separated. Source: Google SketchUp Warehouse Material by BMM. Edited by Yuen Tsang.

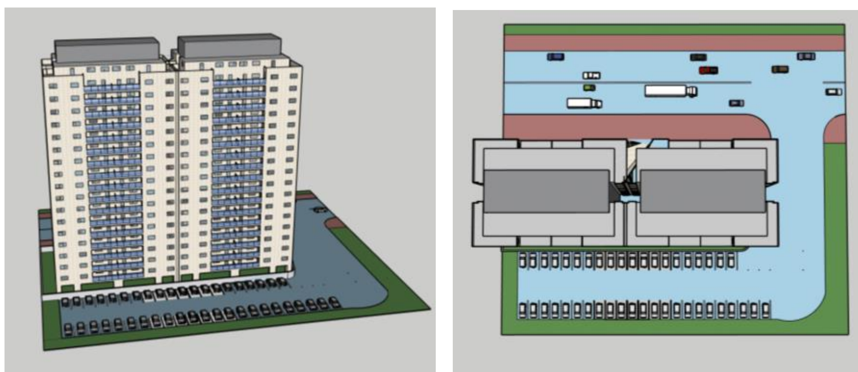

Figure 2-2(a) and (b). The second type of topological relation between buildings: both the buildings make contact

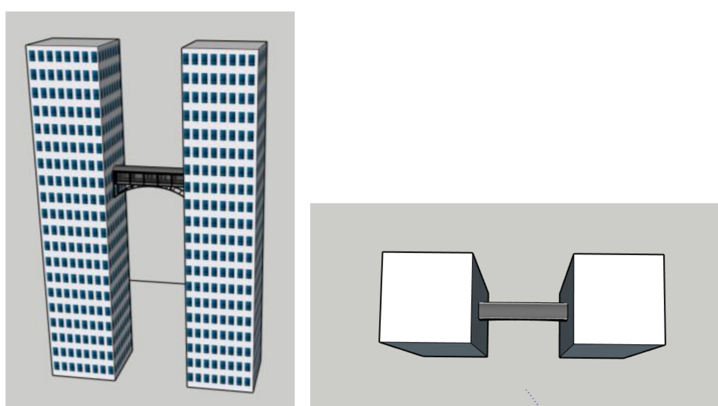

Figure 2-3 (a) and (b). The third type of topological relation between buildings: a connection (overpass, bridge, lobby) between buildings. Source: Google SketchUp Warehouse Material by Billy the Kid™ . Edited by Yuen Tsang.

Appleyard (1969) suggests an important point to emphasize the need to study the topological relation between building and the city's imageable quality. He proposed that the component attributes of buildings, which were predicted as contributing to their image, were the intensity and singularity of their apparent movement, contour, size, shape, surface, quality, and signs (Appleyard, 1969). He agreed that the complexity of the building's shape can capture the attention of inhabitants and serve as a variable in constructing the building's recognition. Despite Appleyard's attempt to explain the relationship between building attributes and a city's image, he did not include the significance of vegetation in his spatial model of urban knowledge.

The topological relations of urban buildings can be expressed in simple geometry. For a single stand-alone building, the relationship between linear line segments and each face (plane) of the building polygon is illustrated in Figure 2-4(a); *n* line segments L_i create the $\boldsymbol{P}_i$ planes of the faces of this building.

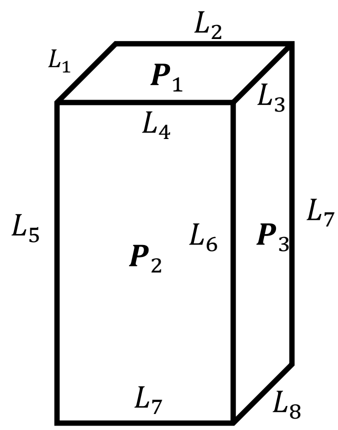

Figure 2-4 (a). Building faces as expressed in line segments (*L*) and plane (*P*).

When two buildings are adjoining, the plane $\boldsymbol{P}_3$ and line segments L_5 and L_1 are shared by the left building and the right building (Figure 2-4 (b) and (c)).

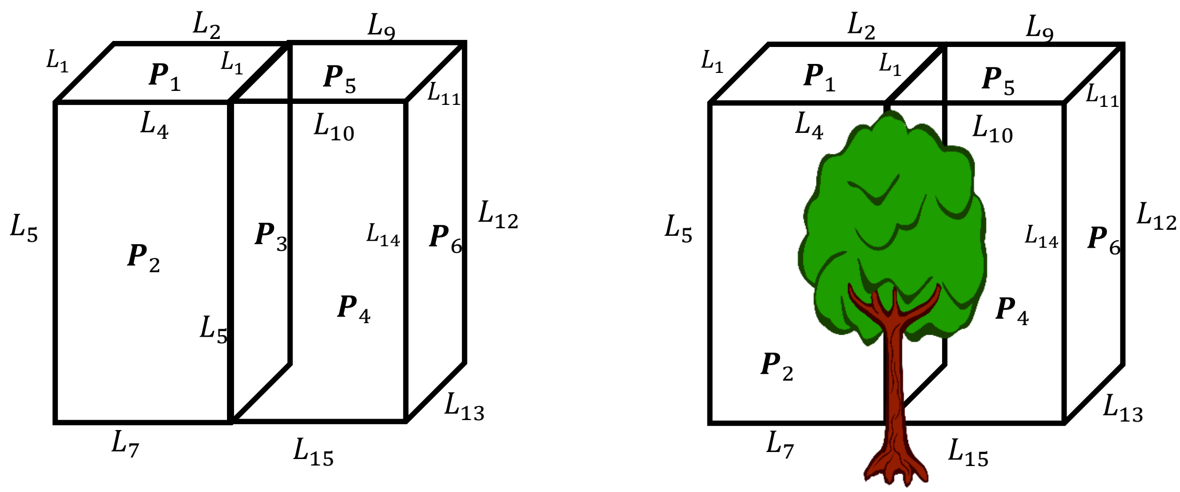

Figure 2-4 (b). Left: Buildings are adjoining.
Figure 2-4(c). Right: A tree blocks a critical portion of the line segment L_5.

If vegetation is present in the scene presented above and blocks a significant portion of L_5 along the line of sight of an observer[1], the observer may have difficulty in identifying and recognizing the correct number of buildings. Frueh et al. (2004) developed an approach to find line segments from oblique aerial imageries for the creation of 3D buildings in a city model. Brenner et al. (2001) attempted to reconstruct buildings for a 3D city model by using 2D ground plan of buildings. Their approach involves inferring from the ground plan how the body of buildings is represented. However, both the approaches overlook the presence of vegetation, creating false edges and shorter line segments. To further explain the drawback of both the

[1] Figure 2-4c is not in an actual scale. The height of the vegetation should not exceed the height of the building in reality. This Figure is used only to depict the scenario when vegetation appears to block the L_5 when the vegetation is situated along the LOS of the observer. The tree appears to be bigger when it situated near to the observer, which blocks a significant portion of L_5.

approaches, it is evident that L_5 cannot be fully extracted from oblique imageries because of the obstruction of a tree. Frueh et al. (2004) acknowledged the fact that there are numerous false edges in the final selection of line segments due to trees, street marks, windows, and other objects but did not further explain how vegetation actually hampers the processes of line identification and extraction of urban buildings in photogrammetry. Brenner et al. (2001) failed to include the factors of vegetation during the creation of the city model because overhanging vegetation can obstruct a significant part of the building's body. Both Frueh et al. (2004) and Brenner et al. (2001) failed to take vegetation into consideration during the building extraction process from oblique images. If vegetation blocks a critical portion of a structure from the viewpoint of oblique images, then a critical portion of a structure can only be constructed by estimation or inference.

By understanding the interrelationship between the building structure and its surrounding vegetation, oblique aerial images or ground images can be taken at locations where the building's recognizability is maximized, thus improving the accuracy of line identification and extraction process of the building polygon. This means that the creation of a 3D city model can depict the real-world urban environment more precisely.

2.2 Isovist, visibility, and recognizability

In order to further understand the theme of recognizability of this research, one has to understand conventional geospatial concepts about perceiving space. The concepts of isovist and visibility have been studied for many years. Many scholars have devoted their lives to investigate these concepts with the application of GIS. Unfortunately, very little research has contributed toward the concept of recognizability with the application of GIS. The following sections illustrate and differentiate the concepts of isovist, visibility, and recognizability in the context of geospatial information science.

2.2.1 Isovist

The isovist concept has been used for spatial analysis and architectural purposes for several decades. Benedikt (1979) coined the term “isovist” to define a set of points that are visible from a vantage (observer) point in space. He applied the notion of isovist in interpreting the perception of architectural space, where the set of points in a polygon region *A* (area in yellow color) are visible from a point *X* (Figure 2-5). Suleiman et al. (2012) illustrated applications of the isovist approach in the field of urban planning, navigation systems, visual surveillance, publicity placement, and wireless network architecture.

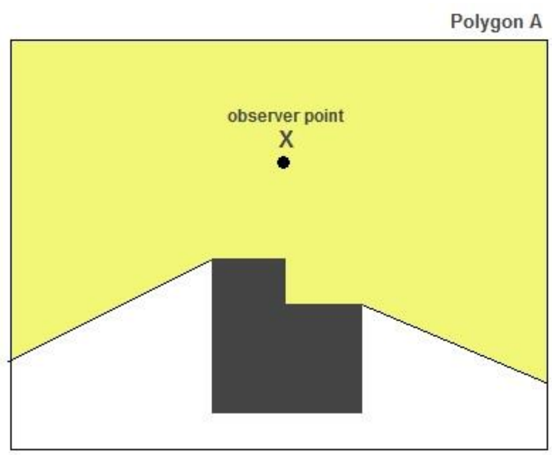

Figure 2-5. Illustration of isovist.

In a real world application, the isovist approach should consider the terrain when computing the visibility field in both rural and urban landscapes. While the natural terrain in many mega-metropolitan cities of the world is relatively flat, densely-clustered buildings have the most significant impact on its visibility. Lake et al. (2000) attempted to solve this problem by creating a digital terrain model (DTM) that combines the elevation of land with building heights. They did not incorporate vegetation effects in their "urban DEM," as they believe that vegetation is difficult to represent due to its semi-transparent nature and seasonal variation (Lake et al., 2000). Both Benedikt (1979) and Lake et al. (2000) lacked attention in understanding how vegetation potentially hinders the viewer's perception and recognition of urban buildings spatially across a 3D urban space. Despite the fact that Benedikt (1979) developed a novel concept of "isovist," the urban environment of the 21st century is far too complicated from the late 70's, when he had first published his work. According to the recent publication by the World Economic Forum [2](2018), there is a global movement to encourage cities to grow more trees and plan more parks. The spatial configuration of 21st century cities complicates the simple isovist concept proposed by Benedikt (1979).

2.2.2 Visibility

Buildings

A complex and populous urban environment such as the New York City comprises a matrix of skyscrapers with different heights, shapes, and designs. Skyscrapers and buildings can be easily accessed by pedestrians, tourists, or New Yorkers within walking distance. However, objects, such as urban trees, overpasses, or signs, which may be situated between an individual and the building may act as an obstruction in clearly seeing and recognizing the buildings. Technically, a *line of sight* (LOS) is "a line between two points that shows the parts of surface along the line that are visible to or hidden from an observer" (Bratt & Booth, 2002). The

[2] World Economic Forum, "There are the 19 cities with the most trees", https://www.weforum.org/agenda/2018/03/the-12-cities-with-the-most-trees-around-the-world. Published on March 26,2018.

viewshed, according to Bratt and Booth (2000), identifies the cells in a raster database, which are visible from one or more observation points and/or lines. Lines of sight are used for constructing this viewshed.

Yin et al. (2012) incorporated the concept of LOS in the visibility analysis of buildings through a two-step process: first, they determined which are the buildings that need to be evaluated in the analysis. The diagram shown in Figure 2-6 demonstrates the position of three buildings along the projected LOS, from V' to T'. The first building a_1 is the nearest to the vantage point and completely blocks the LOS. As a result, the following buildings in the sequence (a_2 and a_3) are not considered for calculation in the visibility analysis.

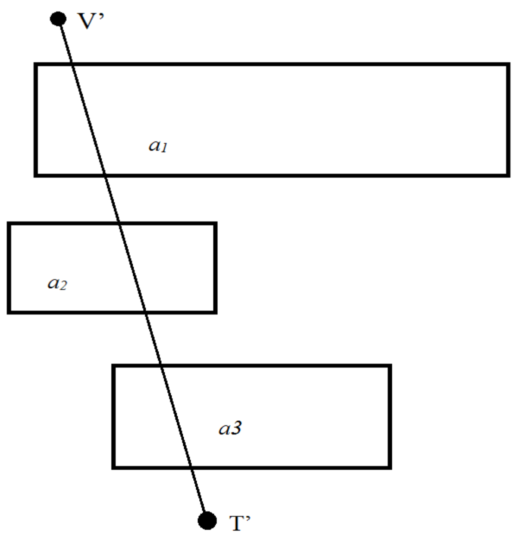

Figure 2-6. Projected LOS from V' to T' and building profiles.

Yin et al. (2012) also used the parallel projection approach to find the building polygons that blocked the LOS. This approach applies the simple logic that if there is a building or object intersecting with the LOS, the observer's view of the target object is blocked and, thus, neither the observer point nor the target point are visible. A projected plane is made perpendicular to the

LOS. The building polygon is then projected on the projected plane. If V' is located inside the projected polygon of the building, the LOS is blocked by that building. A drawback of this approach of visibility analysis is that it takes a lot of time to construct projected planes in complex urban environment with thousands of buildings.

Yin et al. (2012) also highlighted that technical challenges exist when calculating the visibility across urban buildings with this projected plane approach. Their approaches are not well-suited in the actual urban environment, as many other vision-obstructing objects such as vegetation are situated between the V' and T'. These vision-obstructing objects can completely or partially block the visibility of the target from the viewer. For instance, an individual still has the ability to see the target building partially through spaces between tree branches and underneath tree canopies. Visibility also varies seasonally during "leaf-off" conditions. Oftentimes, the viewer has managed to correctly recognize and identify the building even though only a small portion of the building is visible. An individual can easily recognize the famous Empire State Building in New York City from different observation points in the city, even though only the roofline of the building may be visible. This indicates there is some sort of spatial relationship between the observation points, the target building, and the ability of an individual to not only see but also recognize the target. Yin et al. (2012) and other authors' findings do not explain this spatial relationship in the context of recognizability in their studies.

Vegetation

Vegetation not only provides a significant scenic value in a concrete jungle, it also acts a local landmark and tourist attraction in a mega-city. For instance, Central Park in New York City is not only considered one of most famous parks in the world but also serves as a popular landmark and icon of the Big Apple. As urban trees and other vegetation have been widely introduced in metropolitan cities, vegetation has become an essential element in high-density urban areas (Yuan et al., 2017). Architecturally, trees increase visual diversity and complexity to an urban environment (Rapoport & Hawks, 1970). Vegetation in urban environments also functions as a screen or buffer between incompatible land uses (Smardon, 1988). Past studies that have investigated the function of urban vegetation have mostly focused on human's cognitive, psychological, and physiological wellness (Sheets et al., 1991; Smardon, 1988).). As already mentioned in the previous section of this dissertation, no research has yet identified the spatial relationship of urban vegetation and observer's ability to recognize the building accurately along the line of sight.

For instance, the presence of dense trees in urban parks in New York can pose a significant obstacle on the generated visibility and the result of viewshed. Joggers and visitors in Central Park may not be able to see or distinguish the number of neighboring buildings on 5th Avenue correctly, as canopies of trees and vegetation may block the view according to different seasons and various degrees of the transparency of trees. Rød et al. (2009) developed a weighing function to express the transparency of trees in calculating the total visibility at a point. The following formula shows that weight "w" is the relative blocking magnitude of trees while V_{bf} is the visibility of based on a surface that includes both buildings and forest:

$$V = w_{bf} V_{bf} + w_b V_b$$

where V_b is the visibility based on a surface that only includes buildings (Rød et al., 2009).

Weights are relatively subjective according to one's interpretation of transparency. Rød et al. (2009) did not mention in detail the criteria to determine the weight or the blocking magnitude. Dean (1997) proposed another approach to improve the prediction of visibility of trees in forests using estimates of opacity and visual permeability value. The density of trees in an urban park is not uniform in reality. Some areas may have patches of dense vegetation and trees. The variation in the tree density during spring and fall seasons can be much greater than that in summer and winter. Instead of differentiating regions with different vegetation density, Dean's permeability coefficient is applied to the entire region, assuming the density of vegetation is constant.

On the other hand, a high density of vegetation or full foliage can block significant portions of faces of urban buildings. An urban environment comprises complicated built structures and developments, all of which can introduce complications in visibility analysis. As mentioned in the previous section, increasing the numbers of trees and parks in cities not only obstructs the view of many built structures but also obstructs a significant portion of a structure, in particular, thus, reducing the recognizability of that structure to inhabitants.

2.2.3 Recognizability

What is recognizability?

In simple terms, recognizability can be defined as the ability of a viewer to correctly identify and recognize an object across a geographical space. It is also the ability of a person to identify an object from their knowledge of its appearance or characteristics. While GIS can map visibility to demonstrate how a point is visible, no previous research introduced the application of GIS to investigate the attributes of influencing recognizability of urban objects.

As both the recognizability and visibility of a building encompass spatial components, the concept of "recognizability" is commonly considered similar to that of "visibility." The distance between an observer and the target objects (buildings) serves as an essential variable in visibility analysis (Pearson et al., 2014; Pyysalo et al., 2009). Principally, the visibility of an object declines when the distance between the observer and the target object increases. However, the recognizability of the same target object operates in a different fashion. Recognizability comprises spatial components as well. In a complex and clustered urban environment, the target building such as a skyscraper appears as visible to an observer at a near distance.

Heath et al. (2000) explained the "distant view" of a building can be defined as the one in which the building forms only one element of a larger scene. In Heath's early study (1971), he suggested that the scene and the building itself at a distant range of 1 kilometer are perceived as flat patterns. Color variations are insignificant compared to tonal variations. The finer detail of that building is lost as well. Heath et al. (2000) stated that distance also tends to decrease involvement.

However, the recognizability of this target can be low, although the distance between the observer and the target is small. Heath et al. (2000) mainly focused on quantification of the visual complexity of tall buildings at a distance range. They did not consider the surrounding vegetation, which may increase the visual complexity, because the observer may have difficulty identifying or recognizing the target accurately (i.e., correctly naming the building or identifying the numbers of the building). This is because vegetation obscures the significant portion of the target along the line of sight. This illustration explains a twofold scenario: first, the fundamental concept of visibility is dissimilar to recognizability; and second, the distance and the recognizability of objects may not always conform to a linear relationship. Figure 2-7 further explains the relationship between visibility and recognizability. The building in the center of the Figure is visible within the entire region (both blue and shaded areas). However, it can only be completely recognized by observers within the shaded region. One of the key concepts presented here is that the building can be visible from far away but not from the observer's location at the blue region. The spatial relationship between the observer, the trees situated along the line of sight, and the target building can be the potential factor influencing the recognizability of the target building.

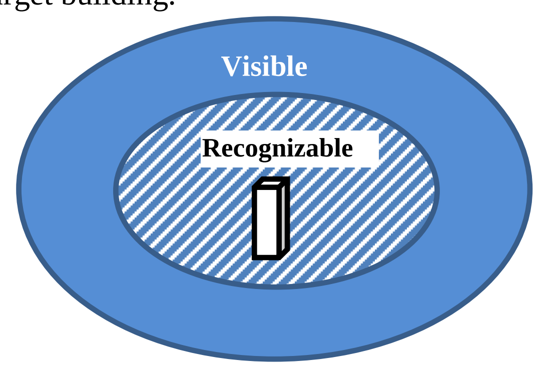

Figure 2-7. The spatial relationship between "visibility" and "recognizability."

Recognizability, physical attributes of buildings, and surrounding vegetation

Heath et al. (2000) found that the perceived complexity of buildings can be attributed to their silhouette and the articulation or subdivision of their façade. Figure 2-8 demonstrates the different building profiles proposed by Heath et al. (2000). They suggested that changes in the profiles of urban buildings can be linked to changes in the perceived complexity of building façades. Heath et al. (2000) agreed that fog obscures details of building façades or if the building is backlit by the rising and setting positions of the sun. Either of the above may alter the perceived complexity of buildings. The work of Heath et al (2000) first links the profile and façades of buildings to human perception by quantifying the concept of complexity. Their work attempts to assume that the perceived complexity of tall buildings from a distance depends on three variables: the number of elements, the asymmetry of shape, and the asymmetry of arrangement.

In fact, the surrounding vegetation near a tall building may increase or decrease its perceived complexity. For instance, if the vegetation obscures the most complicated section of the building façade, the perceived complexity may diminish. Heath et al. (2000) proposed a qualitative and quantitative approach to investigate such an inter-relationship between human perception and physical attributes of tall buildings. Unfortunately, Heath et al. (2000) did not provide any information regarding how vegetation may alter human perception in this context. This flaw of their research actually encourages this research to investigate how vegetation can obstruct human perception and recognition of buildings. Even though Heath et al. (2000) overlooked the vegetative factor in their study, they demonstrated how human perception of an urban object can be determined by the physical attributes of that object.

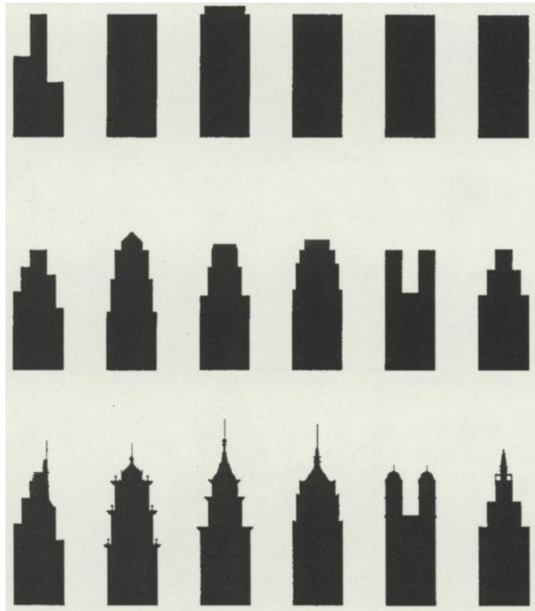

Figure 2-8. Profiles of the buildings, as suggested in the study of Heath et al. (2000)[3]

Indeed, buildings are considered important in creating a memorable view of a city. Considering this role, buildings can make significant visual contributions to a city. Samavatekbatan et al. (2016) claimed that tall buildings are among the most important factors of a city's settings. According to their study, regarding the visual impact of tall buildings, their height is considered primary followed by the complexity of their top. Several studies have also attempted to investigate the relationship between the physical attributes of a building and the corresponding aesthetic quality in a city (Nasar, 2001; Stamps, 2002; Zacharias, 1999). The physical features, shape, and profile of a building not only influence the aesthetic quality but also how people remember and recognize the building (Lynch, 1960).

[3] Heath, T., Smith, S. G., & Lim, B. (2000). Tall Buildings and the Urban Skyline: The Effect of Visual Complexity on Preferences. Environment and Behavior, 32(4), 541–556. © 2000 Sage Publications, Inc.

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Similar to the concept of complexity illustrated in Heath et al.'s (2000) study, the concept of the recognizability of a building can also be understood through the human perception and the physical attributes of buildings. In regard to building shapes, as demonstrated by Heath et al. (2000) in Figure 2-8, some buildings have different towers that are not linked through a shared ground base (Figure 2-9). A method of obtaining good recognizability is determined by learning how viewers correctly identify one basic aspect of a building's recognizability—whether or not the observable portions of one or more buildings are connected and hence constitute a single building or are not connected and hence constitute two or more buildings.

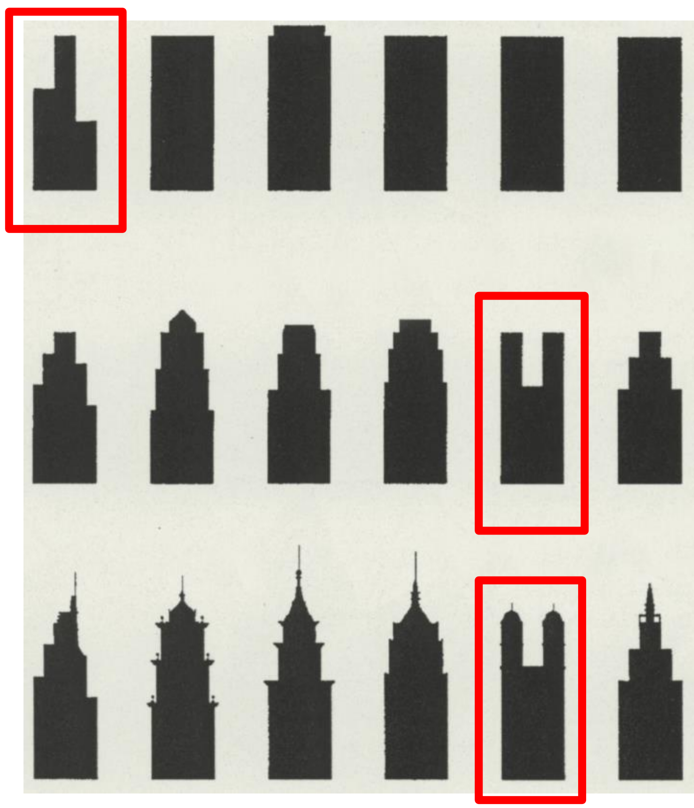

Figure 2-9. Buildings with towers and shared ground base.

By using the simple method mentioned above, recognizability can be better quantified. This method assumes that if an observer cannot clearly see the entire structure of a building due to the obstruction of trees along the line of sight, then the observer may predict the number of buildings incorrectly. Under this scenario, the shared-base of a building is blocked while only the towers are visible. This may confuse the visual perception and recognition of an observer because then one building may appear as two separate buildings. If the shape of this building comprises significant values to visual aesthetic value and iconic status to tourists or inhabitants, its low recognizability definitely hampers the "image" of a city. Lynch (1960) and Appleyard (1969) emphasized how the "image" of a city is important to architects, city planners, and inhabitants; however, until now, no approach has been seen to integrate the attributes of recognizability of a building into the creation of "image" of the city.

As mentioned earlier, geospatial information sciences focus on studying the spatial relationship between humans and objects on Earth. Such relationships can be incorporated into a unique spatial configuration for each city. Karimimoshaver et al. (2018) explained that the way by which an urban element is related to other surrounding elements in a city defines the meaning of that element. They implied that the meaning of an element (a building) is not a derivation of itself. Hasting (1944) in his early study suggested the pattern on an urban scale is to be found "*in the visual relationships of buildings with buildings or buildings with trees*" (Hastings, 1944; Gassner, 2013). As more cities are moving toward a "greener" planet by planting more trees (World Economic Forum, 2018), relationships or association between buildings and trees are gaining more importance and complication.

Recognizability and human factors

Previous scholarly works that studied and evaluated the visual effects of vegetation in urban environments have been mostly based on quality (Schroeder et al., 1986; Tyrvainen et al., 2003). Different sets of videos and photographs of urban forests are ranked by a group of people. The goal here is to evaluate the visual effects of urban forests according to the respondents' preferences. Yang et al. (2009) argued that this method of ranking can provide variable results, as the cultural backgrounds and personal or psychological attributes of respondents vary (Yang et el., 2009; Aoki, 1999). They found that people with British and Asian origins react differently to shady trees and open spaces. Consequently, the function of recognizability of urban objects seems to include an additional dimension— the sociodemographic profile of respondents. For instance, a resident of New York City may be able to recognize the correct number of a building because they are familiar with the surroundings of this city. Contrarily, a resident from a rural area may recognize the same building in a different manner.

Dean and Lizarraga-Blackard (2007) attempted to quantify the magnitude and spatial distribution of aesthetic impacts of the objects in a non-urban environment and suggested that the aesthetic impacts of forest clearcuts diminish with increasing viewing distance. Their study involved developing a GIS-base model to estimate how screening vegetation affects the magnitude and spatial distribution of the aesthetic impacts of clearcuts. Respondents with different sociodemographic characteristics are asked to rate photographs of the clearcuts taken from Colorado forests. Their research inspires and assures the possibility of applying spatial modeling to quantify intangible values, such as scenic beauty and aesthetic preferences.

Dean and Lizarraga-Blackard (2007) developed “perceived-scenic-beauty” rankings for each photograph in accordance with the Law of Comparative Judgments (LCJ) technique. The main goal of this technique is to allow respondents to compare all possible pairs of photographs and decide which photograph in each pair is more scenic. The LCJ method has been recognized to be one of the most important approaches to rank the perception of scenic beauty in non-urban environments since its development by Buhyoff and Leuschner in 1978. Until now, only a few researchers have used this approach to rank the perception of other intangible values such as recognizability in an urban environment. On the other hand, one of the pitfalls of Dean and Lizarraga-Blackard’s (2007) research is the lack of consideration of potential influences that are induced by sociodemographic differences of the respondents to the result. This echoes the conclusion by Yang et al. (2009) that research conclusions can vary due to differing cultural backgrounds, and personal attributes of survey respondents.

Recognizability and distance

Apart from the demographic factors of the respondents, the distance between the observer and the target serves as one the most important factors of governing recognizability. According to the conventional distance decay model in geographic literature, the interaction between two locales or objects diminishes as the distance between them increases.

Nekola and White (1999) restated the distance decay gravity function as:

$$I = A * d^{-c}$$

where I is an amount of interaction, A is a constant, d is the distance, and c is the coefficient of friction .

As explained earlier in this dissertation, there seems to be a non-linear relationship between the recognizability of the target building and the distance between the observation point and the observation target. The recognizability of this target can be low, although the distance between the observer and the target is small. One major reason behind this is the presence of urban trees along the line of sight. Urban trees may block the critical part of the observation target such that observer loses ability to correctly recognize the building.

Figure 2-10 explains a conventional distance decay model in geographical studies. This conventional distance gravity model illustrates that the level of interaction reaches minimum if the distance is large. In fact, contrary to this model, the recognizability of the target may increase at a long-distance observation locale. Urban trees may no longer obstruct the critical and iconic part of the target and, hence, the target may be clearly visible and recognizable from a long distance.

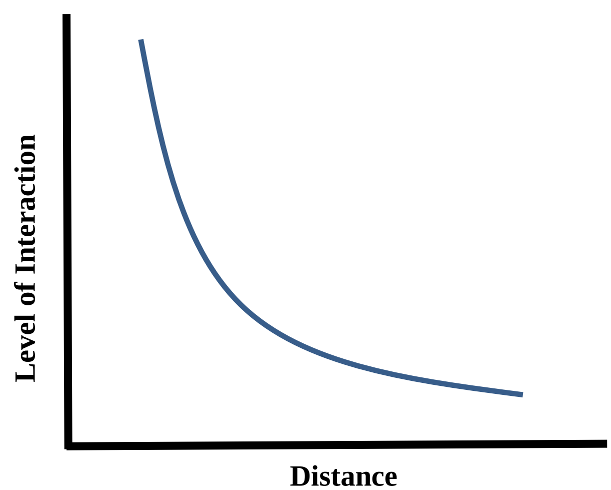

Figure 2-10. The distance decay model.

Appleyad (1969) developed a qualitative and quantitative study to predict how buildings are recalled by respondents. According to his research, the major assumption that an inhabitant would recall a building are due to four reasons: (1) the distinctiveness of the building's physical form, that is, its "imagebility" (Lynch, 1960); (2) its visibility when one is travelling around the city; (3) its role as a setting for personal activities, use, and others; and (4) the inferences made by an inhabitant on its cultural significance to the population at large. For the first reason, Appleyad suggests that the distinct form of a facility in general was accessed from a viewpoint in front of its main entrance or within an inhabitant's line of sight. Any noticeable qualities which made that building stand out were rated. For the second reason, Appleyard defines "visibility" as three tenets: viewpoint intensity, viewpoint significance, and immediacy. High visibility in terms of viewpoint intensity is expressed, as the building is visible from main east-west roads. If a building has a high visibility, then it comprises a high viewpoint, from where it is visible to major destination points, intersections, bus stops, and ferry landings on major roads. If a building is close to the axis, cutting across the line of vision on major roads, then it has high immediacy and visibility.

Based on the assumptions and definitions provided above, it can be said that a building's recall rate is determined mostly by its visibility from the main road system. Some locations given in his study are remote, unseen, and open only to an exclusive few (such as the socially prestigious Country Club in Ciudad Guyana); yet these locations are widely known by the respondents of his research. The result of his study concludes that the locations of the building or its relative distances from the respondent do not correlate with the significance of the building.

Appleyard (1969) study explores other historical, social, and human attributes that significantly influence the recall rate of the building.

2.3 Summary

Understanding how buildings are recognized may help improve a city's image and urban planning, offer better ex ante photographs for landscape projects, and make the iconic portion of a significant building recognizable for navigation purposes.

In summary, the above conventional approaches, such as isovist and visibility methods, cannot fully depict and quantify the actual impact of urban vegetation on the ability of an observer to correctly recognize urban buildings. Instead, this dissertation has made an attempt to develop an approach that investigates the attributes of recognizability by taking the following into consideration: first, the topological relation of urban objects is considered as a form of 3D approach, which mimics the way humans correctly or incorrectly recognize buildings. Previous literatures (Heath et al., 2000; Appleyard, 1969) focus on correlating physical features of buildings with perceived complexity, visual aesthetic quality, and recall rate. No existing literature has made an attempt to study the influence of topological relation of urban objects and physical attributes of buildings on human perception of a building; hence, recognizability.

Second, the presence of urban vegetation with different heights directly increases or decreases an observer's ability to correctly identify or recognize the target building. Accordingly, the spatial distribution of observer points in relation to urban vegetation can influence an object's recognizability in a complex urban environment. Current literatures address the impact of vegetation on the visibility of objects in a rural or forested area. There is a lack of literatures when examining how vegetation obstructs the critical portion of buildings and hence reduces an observer's ability to recognize the building.

Third, this dissertation also attempts to study how distance influences the recognizability of buildings. This relationship has not been studied by previous researchers, as some previous studies have attempted to study the relationship of distance and visual aesthetic quality in non-urban environments. Other researches study humans' perception of buildings from a distance but not mid-way or closer.

Finally, the socio-demographic characteristics of observers can influence the accuracy of object recognizability as well. However, no existing research related to how socio-demographic factor influence an observers, such as age, familiarity of a place, education level, or other variables can potentially influence the ability to recognize the building have been published.

Attempts in this dissertation have been made to develop a quantitative approach to include all four factors that provide a better understanding of urban object recognizability in the realm of geospatial information science. The goal of this dissertation is to fill the gaps of existing literature regarding the human recognition of buildings in urban environments.

CHAPTER 3

METHODOLOGY

This dissertation attempts to demonstrate a quantitative approach to provide a method to predict potential attributes that influence recognizability of buildings in a complex environment such as New York City. Figure 3-1 below illustrates an overall structure of this dissertation.

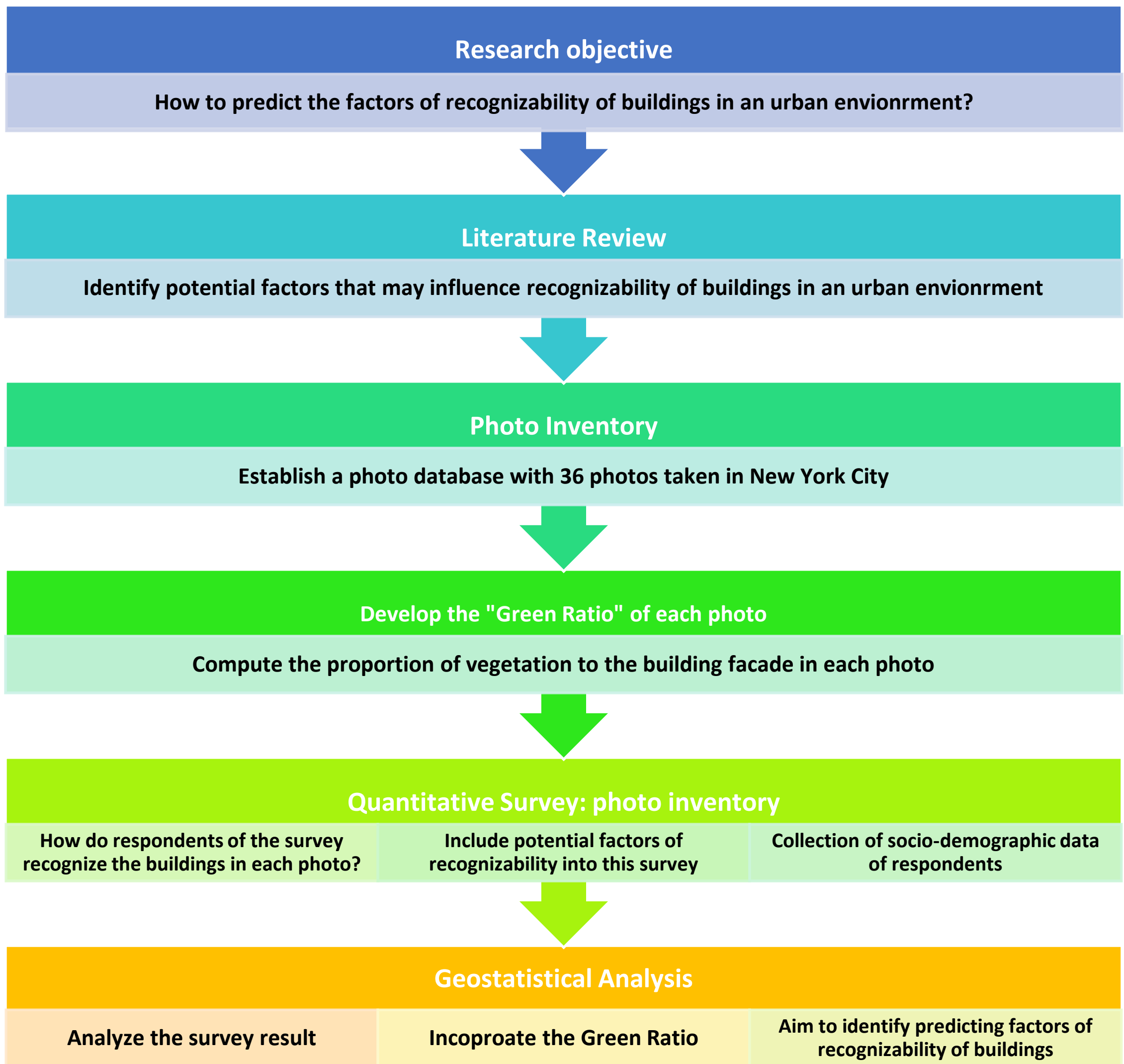

Figure 3-1. Overall structure of this dissertation.

The earlier section of this dissertation explores and identifies existing research gaps related to the issues of visual recognition of urban buildings. In fact, no existing research explicitly explores the factors of recognizability of buildings in an urban environment from a geospatial information sciences perspective. From the investigation of closely-related literature about this topic, the building visual recognition (or recognizability) can be investigated according to several factors: 1. Viewing distance between an observer and the building 2. Physical attributes or topological relations of buildings 3. Surrounding vegetation 4. Socio-demographic characteristics of an observer.

Existing conventional GIS-based visibility analyses do not explicitly explain the component of human visual recognition and identification of an object. In simple terms, the results of visibility analyses explain "what can be seen or cannot be seen". In reality, an urban object sometimes cannot be recognized even if is visible or "it is seen". In order to better understanding the visual recognition of buildings in a city, this dissertation aims to use real city photos as sources of data to best study how humans recognize the urban environment in a real 3-Dimensional spatial configuration.

3.1 Photo Inventory

Previous scholars have been working with perception-related parameters of urban objects with photographs for recent decades (Pardo-García et al., 2017). Karimimoshaver et al. (2017) use photographs from Frankfurt, Germany to assess impacts of tall buildings on the city skyline; Dean and Lizarraga-Blackard (2007) study aesthetic impacts of burn scars in rural Colorado by developing a quantitative approach to analyze photo transects; Nasar and Hong (1999) ask respondents to judge physical features of 19 photographs of retail sign scenes in order to investigate the role of sign obtrusiveness and complexity in the perception and evaluation of urban signscapes. As the main scope of this dissertation is about recognizability, real photographs can well represent to how an urban scene is perceived and recognized from a ground perspective.

Pardo-García et al. (2017) mention several photo-taking techniques such as depth field, focal angle, and panorama view for their GIS study. It cannot be denied that the photo-taking techniques may influence their research conclusions, but the techniques they mentioned are not the focus of this dissertation. In this dissertation, 36 photos of 12 buildings (3 photos for each building) were taken in lower Manhattan in the New York City in late June in 2017. 12 Buildings are selected randomly within a 0.5-mile radius [4]of the high pedestrian volume locations according to the bi-annual pedestrian traffic counts report from the New York City Department of Transportation[5]. It is assumed that the selected buildings may have high exposure to pedestrians on weekdays. Buildings near these high pedestrian volume locations are important to pedestrians' visual memories and recognition of the surrounding area for way-finding or navigation (Lynch, 1969).

[5] New York City Department of Transportation, bi-annual pedestrian traffic counts
http://www.nyc.gov/html/dot/html/about/datafeeds.shtml#Pedestrians

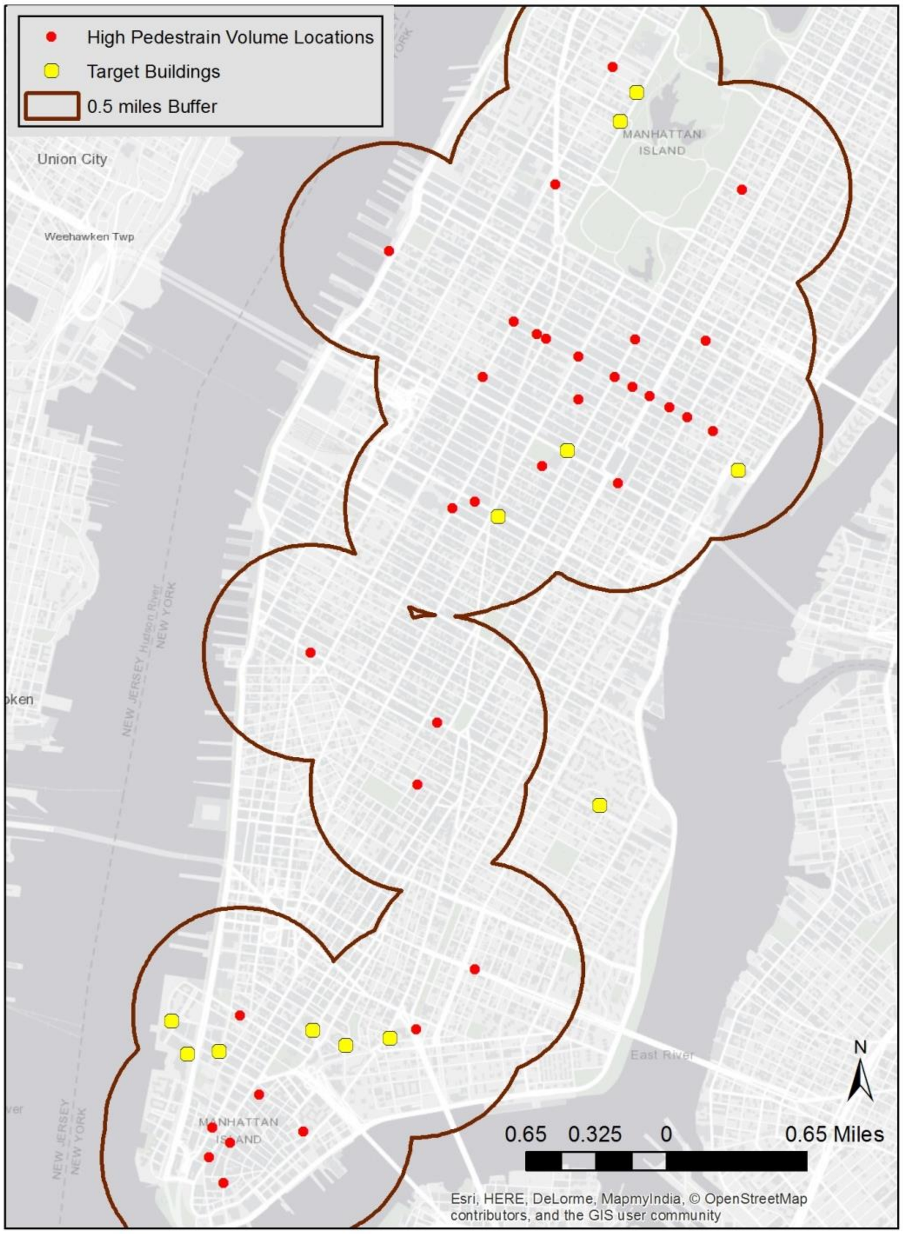

Figure 3-2. Locations of high pedestrians volume and 12 target buildings.

Figure 3-2 is a map showing the high pedestrian traffic locations in New York City on May 17, 2017. The pedestrian counts were collected on the weekday during peak hours by New York City Department of Transportation. The data is imported in ArcGIS 10.6 as shown in figure 3-2. One building in the east is not located within the 0.5 mile zone because of street construction and road closures during the photo-taking day in late June 2017. A near location is selected within the same apartment complex to ensure that the newly selected building is similar to the previous selected one within the construction zone.

A standard digital camera Sony DSC-HX9V with f/3.3 lens was used to film all photos from a ground level. It is assumed that all photos are taken at the same elevation as the elevation of Lower Manhattan is relatively flat. An urban scene of buildings and vegetation is captured for each photo. All photos were taken between 8 am to 5pm to guarantee sufficient sunlight. Photos were captured in late June in 2017 when New York City sets amid lush greenery in the summer season. A landscape of shade trees with dense foliage creates an ideal environment to study how such trees obstruct the recognizability of a target building. This also eliminates any bias due to seasonal changes (Dean and Lizarraga-Blackard, 2007; Buhyoff and Wellman, 1980).

As shown in figure 3-3, target 1 is a high-rise building surrounding by street trees in the heart of Manhattan. A photo was taken from the ground at site X in the near-range zone of target building A with nearby trees. Another snapshot of the target building A and surrounding trees was captured at site Y where this site is located at the middle-range distance from. A final snapshot of the target and nearby trees was captured at site Z, the far-range zone from the target. A photograph transect comprises of three snapshots from site X, Y, and Z. As there are 12 targets in this research, there are 12 photograph transects (3 photos for each transect). The Appendix included all 36 photos (12 transects with 3 photos in each) used in this research. Table 3-1 and figure 3- 4 shows the information and location of the 12 target buildings respectively.

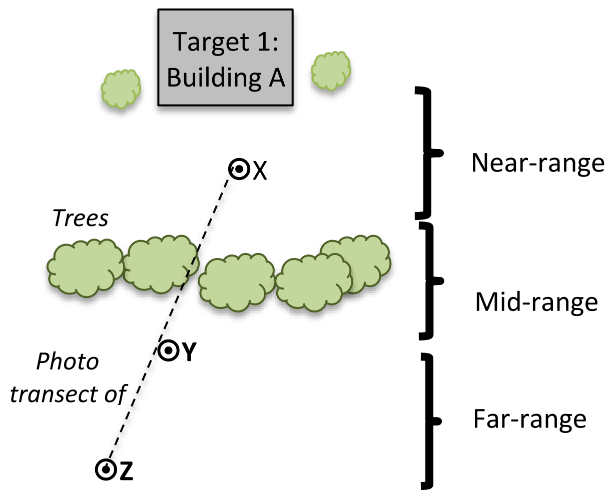

Figure 3-3. Layout of a photo transect around a hypothetical target building

Table 3-1. Information of 12 target buildings.

Building Alias	Building Names	Address
BF Place	Brookfield Place	250 Vesey Street
CF Plaza	Confucius Plaza	2-68 Division Street
Bryant C	500 5th Ave	500 5th Ave
Fitterman	Fitterman Hall	245 Greenwich Street
DPM	Daniel Patrick Moynihan Courthouse	500 Pearl St, New York, NY 10007
River Terrace	The River House	2 River Terrace
Foley Square	US Court of International Trade	1 Federal Plaza
Herald Tower	Herald Tower	1282-1300 Broadway
San Remo	San Remo Apartments	142-148 Central Park West
UN	860 U.N. Plaza Apartments	860-874 1st Avenue
Majestic	Majestic Apartments	115 Central Park West, New York, NY 10023
PC	Stuyvesant Town Apartments VI	535-545 East 14th Street, 521-525 East 14th Street, 627-633 East 14th Street

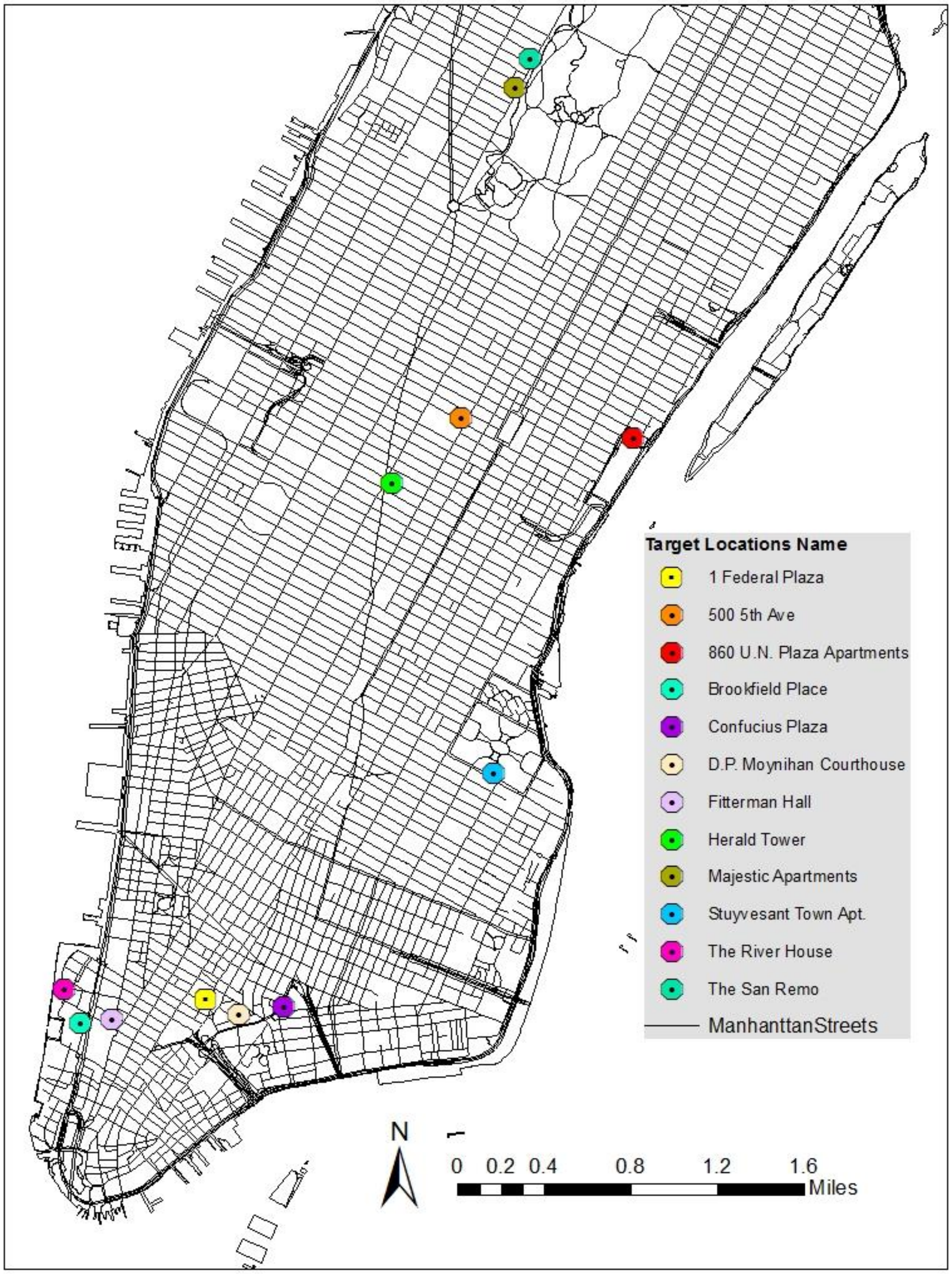

Figure 3-4. Locations and names of 12 target buildings.

The 12 buildings are in fact of different usages of commercial, residential, and governmental activities. All of these buildings are not the worldly renowned buildings such as the Empire State Building, or the Chrysler Building to minimize the recognition bias.

It is nearly impossible to take photos of 12 buildings from uniform ranges of viewing distances in a clustered and compact urban area like Manhattan. Different widths of pedestrian pathways, high traffic conditions and ongoing construction all constrained the standardization of viewing distances. Table 3-2 (a) and (b) lists the distances between the buildings when the photos are taken. The distance is measured using the measurement tool in Google Earth.

Table 3-2 (a) and (b). How the photo is taken: viewing distances (in feet) between the author and the 12 buildings.

	BF Place	CF Plaza	Bryant C	Fitterman	DPM	River Terrace
Close-range	100	60	90	30	100	80
Mid-range	150	200	250	200	200	200
Far-Range	320	500	380	300	300	450

	Foley Square	Herald Tower	San Remo	UN	Majestic	PC
Close-range	100	220	170	80	100	100
Mid-range	200	350	340	200	1050	230
Far-Range	500	450	620	350	1200	300

Figure 3-5(a) Left : San Remo Apartment : picture taken at about 170 feet away from the building. 3-5(b) Middle: picture taken at about 340 feet away from the building. 3-5(c) Right: picture taken at about 620 feet away from the building.

Figure 3-5 (a), (b), and (c) provides a sample of photos in the photo inventory. All identifiers in each photo (faces, building numbers, company logos, street names, and licenses plates) have been blocked or removed by Adobe Photoshop to secure confidentiality. The target building in each photo is highlighted with a yellow line to define the area of recognition.

3.2 Green Ratio

As mentioned earlier, many big cities are transiting into a greener spatial configuration with more trees and parks according to the report by the World Economic Forum in 2018[6]. New York City is no exception. Vegetation is dominant in the urban landscape of the Manhattan area. Figure 3-6 illustrates spatial distribution of street trees in Manhattan. The street data is from the New York Tree Census in 2015 and is processed in ArcMap 10.6. As shown in figure 3-6, street trees and shrubs are obviously common features to situate around property lines of a building.

[6] https://www.weforum.org/agenda/2018/03/the-12-cities-with-the-most-trees-around-the-world

Close proximity of street trees and shrubs to surrounding buildings may obstruct an observer's ability to correctly recognize the building along the line of sight.

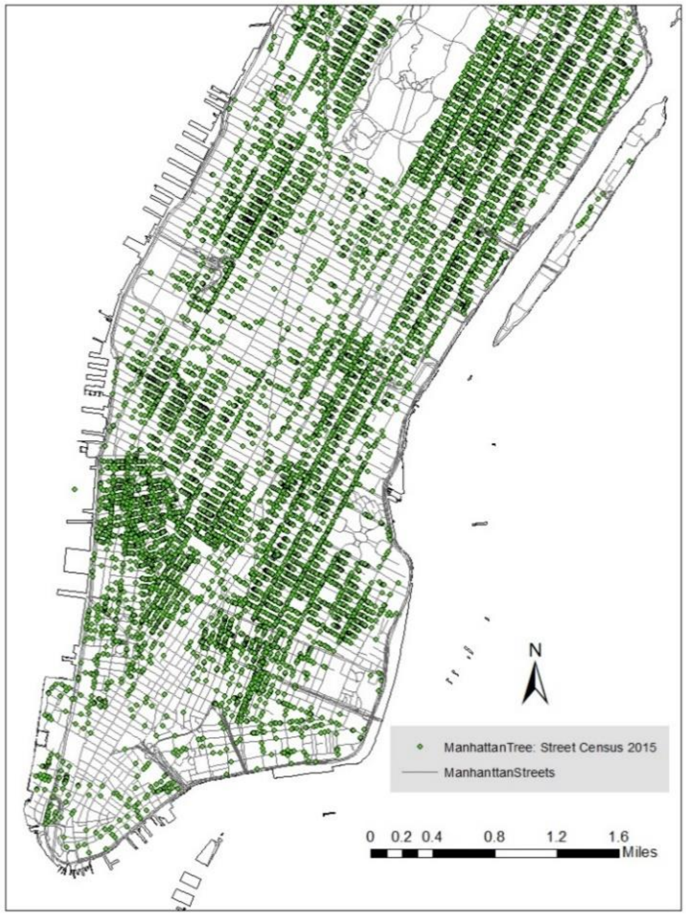

Figure 3-6. Location of street trees in the study area.

In order to better understand what proportion of street trees and shrubs obstruct the target building in each photo, a "Green Ratio" is developed for each photo. This ratio is inspired by the work of Yang et al. (2009), who developed a "Green View" factor to quantify the amount of greenery that people can see on the ground. The goal of their research was to develop a Green View factor to evaluate the visibility of urban forests. The Green View factor was estimated through a combination of field surveys and photographic interpretations and tested in Berkeley, California. The pixels of greenery in each photograph are selected and counted in each photograph. The selected pixels were then divided by the total pixels of the image to get the ratio of the greenery to the total area of the photo. Yang et al. suggest a big limitation of their work:

> *"…the visual quality decided by subtle characteristics of the greenery within view, such as the arrangement of vegetation and buildings, pattern of leaf distribution, and varied colors and textures of foliage, were not addressed in this study. However, those characteristics can have influence on perceptions of the urban forest."*
>
> *(Yang et al., 2009 p.103)*

The Green Ratio method proposed here is different from that of Yang el al. (2009) Green View method. The Green Ratio offers an improved approach to investigate the ratio of greenery to surrounding buildings. The Green Ratio calculates the proportion of greenery that obstructs façades of the target building. This method can help to study the arrangement of vegetation and buildings in which Yang et al. study did not address. The following is a detailed explanation of how the Green Ratio is obtained.

First, the target area is highlighted with yellow line in each photo as seen in figure 3-7. Pixels of all greenery that obstruct the building within the highlighted region are selected by the Magic Ward tool in Adobe Photoshop (figure 3-8). Pixels of the buildings within the highlighted region are also selected by the Magic Ward tool in Adobe Photoshop. The Histogram function in Adobe Photoshop shows the selected pixel counts. Green Ratio is obtained for each photo by the following equation:

$$Green\ Ratio = \frac{Pixel\ counts\ of\ obstructed\ greenary\ within\ the\ hightlighted\ region}{Pixel\ counts\ of\ enrire\ target\ building\ within\ the\ highlighted\ region}$$

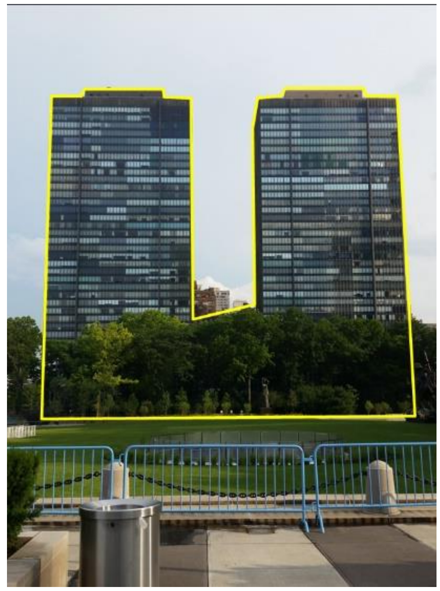

Figure 3-7. Highlighted region in a photo for calculating Green Ratio

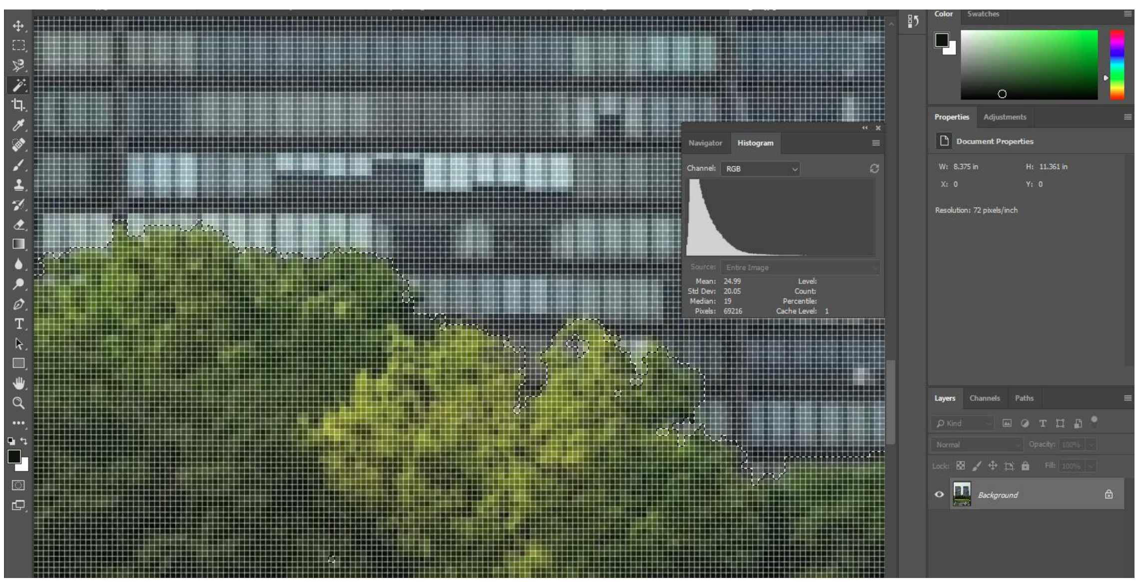

Figure 3-8. Pixels of obstructed greenery are selected using Adobe Photoshop magic ward tool.

Table 3-3. Green Ratio for each photo.

	BF Place close	BF Place mid	BF Place far	River Terrace close	River Terrace mid	River Terrace far	Bryant close	Bryant mid	Bryant far
Obstructed greenery pixel counts	31307	38660	20403	16374	41111	86761	3751	42923	42956
Building pixel counts	336470	181654	158867	150211	78701	264938	152492	76427	197704
Green Ratio (%)	9.30	21.28	12.84	10.90	52.24	32.75	2.46	56.16	21.73

	CF Plaza close	CF Plaza mid	CF Plaza far	DPM close	DPM mid	DPM Far	Fitterman close	Fitterman mid	Fitterman far
Obstructed greenery pixel counts	74016	65227	0	0	26347	110732	0	43521	59214
Building pixel counts	286689	140391	253516	83143	75893	234339	187865	135397	117997
Green Ratio (%)	25.82	46.46	0.00	0.00	34.72	47.25	0.00	32.14	50.18

	Foley close	Foley Mid	Foley Far	Herald Tower close	Herald Tower mid	Herald Tower far	San Remo close	San Remo Mid	San Remo Far
Obstructed greenery pixel counts	71902	259199	34873	0	25341	70935	61753	71326	17957
Building pixel counts	1193965	1055915	112885	77829	58487	219613	162244	104772	56829
Green Ratio (%)	6.02	24.55	30.89	0.00	43.33	32.30	38.06	68.08	31.60

	UN close	UN Mid	UN far	Majestic Close	Majestic Mid	Majestic Far	PC Close	PC Mid	PC Far
Obstructed greenery pixel counts	10833	189103	70856	69423	57358	49934	387587	520905	442794
Building pixel counts	549816	420691	202083	379944	83913	79632	697691	767834	737486
Green Ratio (%)	1.97	44.95	35.06	18.27	68.35	62.71	55.55	67.84	60.04

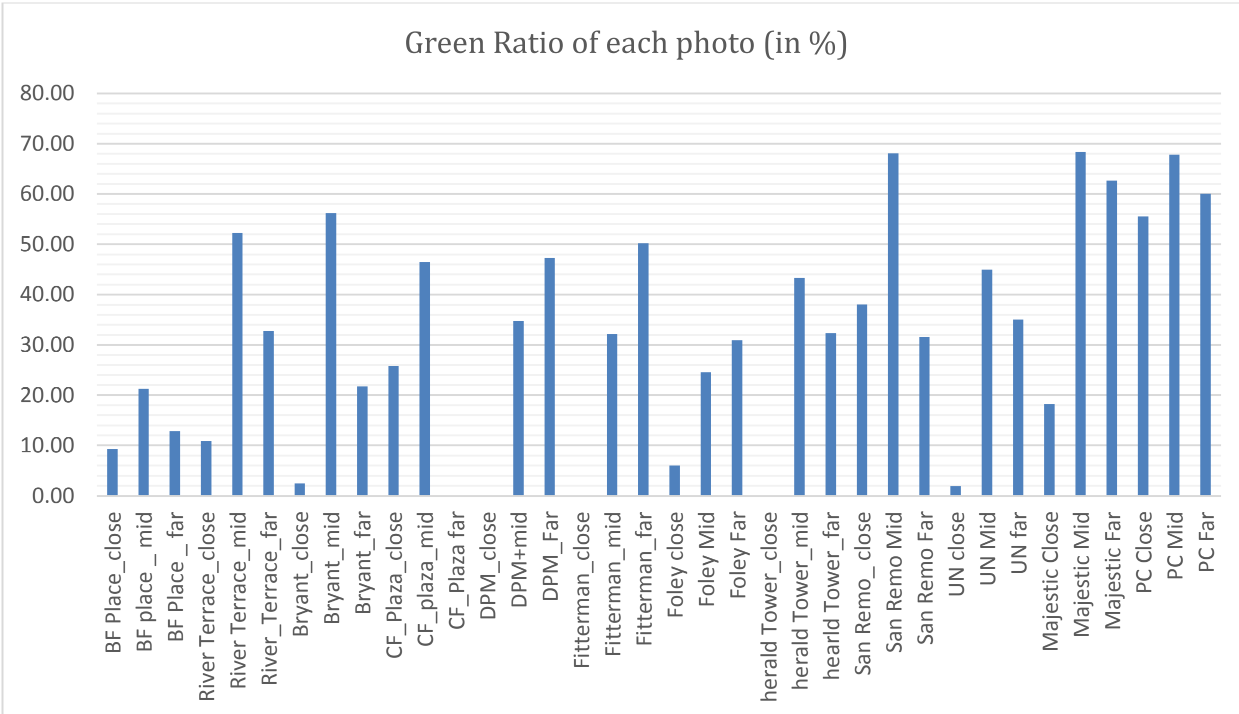

Figure 3-9. Green Ratio of each photo.

Table 3-3 and figure 3-9 illustrate the green ratio of each photo. There are three photos with zero green ratio. There is no greenery within the highlighted region in each of these three photos. Photos of the Majestic Apartment and Peter Copper Village yield the highest green ratio. Trees and shrubs obstruct over at least 50% of the building facade in the photo of the Majestic Apartment building and Peter Copper Village. All Green Ratios will be later incorporated into a quantitative analysis to further investigate how trees and shrubs influence the visual recognition of buildings.

3.3 Quantitative Survey

After the establishment of a Green Ratio, it is important to further investigate how humans actually recognize the buildings from real photos to better understand how recognizability of buildings are attributed. A quantitative survey is developed to gather responses on how participants recognize the building in each photo. All 36 photos from the photo inventory are uploaded to a web-based survey hosted by Qualtrics. Participants of this IRB approved online survey are to complete the survey on computers or other electronic devices (i.e. cell phones or tablets). The survey contains 20 questions, which consists of 12 photo questions and 8 demographic questions. Each photo question contains one single photo that is randomly selected from the photo inventory. The participant is required to answer one question following each photo: how many building(s) can you identify within the highlighted region? Participant has two options to answer the photo question: A. “1 Building” B. “2 or more buildings”. The figure 3-10 below captures a screen-shot of the photo question in this survey:

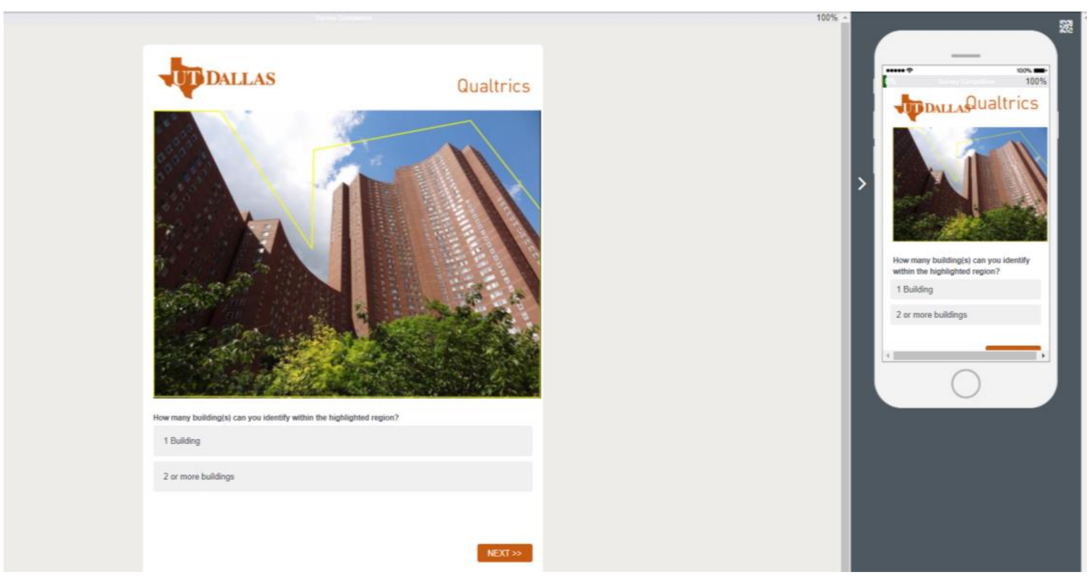

Figure 3-10. A screen-shot of the online survey.

The online survey focuses on how participants recognize the correct number of buildings in each photo. The number of buildings in each photo basically reflects the topological relation of that particular building or buildings. For instance, a building with two towers and one shared base may appear as two separate buildings if trees and shrubs cover the base floors. Hence, it is more meaningful to ask participants to evaluate the number of buildings appearing in the photo rather than the names of the building.

After evaluating 12 photo questions, participants were asked to answer 8 socio-demographic questions. The survey questions are included in the Appendix.

Subjects for participating this IRB - approved online survey were members of the American Association of Geographers (n = 97) varying in age, profession, ethnic background, and socio-demographic status. The survey was distributed through official online portals and group emails of American Association of Geographers from 2/17/2018 to 2/28/2018. No prior training or additional information about each photo was provided. Participant evaluated each photo according to their own perception, experiences, and ability of recognition. All photo questions appear in a stratified random manner in Qualtrics to minimize bias, that is, every respondent has equal chances to evaluate one photo from each transect of the 12 buildings. In other words, all participants are able to evaluate all 12 buildings.

3.4 Compute the Respondent's Correctness

All participant responses were exported from Qualtrics to a database. A Response Correctness (RC) is calculated for each participant. If a participant is able to correctly identify the number of buildings appearing in one photo, a value of "correct" is assigned as the RC of that particular survey record (table 3-4 and 3-5). If a participant identifies the wrong number of the building, the RC for this particular survey record is marked as "incorrect".

Table 3-4. Actual number of buildings of 12 target buildings.

Building Alias	***Number of Buildings***
BF Place	1
CF Plaza	1
Bryant C	2
Fitterman	1
DPM	2
River Terrace	1
Foley Square	2
Herald Tower	1
San Remo	1
UN	1
Majestic	1
PC	2

Table 3-5. The Respondent's correctness (RC) in a database.

Participant	**Building**	**View Range**	**RC**
1	BF	close	
1	CF	close	
1	Bryant	close	
1	Fitterman	close	correct
1	DPM	close	incorrect
1	RiverT	close	
1	Foley	close	incorrect
1	Herald	close	correct
1	SanRemo	close	correct
1	UN	close	
1	Majestic	close	
1	PC	close	correct

3.5 Statistical Analysis

3.5.1 Preparation

Appleyard (1969) developed a regression model for predicting attributes of building recall. He demonstrates the quantitative analysis of attributes of intangible variables such as building recall and human visual perception. Unfortunately, he does not include detailed explanation about statistical procedures of the regression analysis. Despite this drawback, Appleyard offers good insights about the intercorrelations between variables. He explains that attributes such as singularity and intensity of form attributes of buildings are intercorrelated. It may have been unnecessary to distinguish those two variables.

Based on Appleyard's study, it is vital to study the intercorrelations between variables to provide more accurate statistical results. The multicollinearity of independent variables will be tested to check if there are interrelationships between these variables.

Table 3-6. A sample of the complied database prepared for the statistical analysis.

Participant ID	Building	Range	RC	Var 1	Var 2	Var 3	Var 4	Var 5	Var 6	Var 7	Var 8	Var 9	Green Ratio
1	BF	far											12.84281821
1	Bryant	far											21.72743091
1	CF	far											0
1	DPM	close											0
1	Fitterman	close											0
1	Foley	close											6.022119576
1	Herald	close											0
1	Majestic	far											62.70594736

Before the execution of statistical analysis of the survey result and green ratio, all collected and computed data (RC and Green Ratio) need to be compiled into one database.

The database combines the survey result and the other potential attributes of contributing to the RC value. Table 3-4 captures the structure of the database. Columns of Var 1 to Var 9 will store the independent variables of this analysis (table 3-6). The majority of the variables are categorical. The categories of each variable are listed in table 3-7. Data for variables 2 to 9 comes from the survey. The data are primarily social and demographical. Appleyard (1969) suggests that the presence of an array of social-demographic attributes might be critical promoting building recall. In his study, he uses age, sex, education, familiarity with the city, respondent's physical mobility, and their travel mode as independent variables of the analysis. So it is reasonable to include independent variables Var 2 to Var 9 (table 3-7) in this study to explore how the socio-demographic characteristics of respondents may influence their visual recognition of buildings in each photo.

Table 3-7. Information about independent variables of this research.

	Descriptions of Variable	**Source**
Var 1: "Distance"	Distance away from the building in each photo	Measurement from Google Earth
Var 2: "Age"	Age of respondents – categorical	Survey result
Var 3: "Gender"	Gender of respondents - categorical	Survey result
Var 4: "Education"	Education attainment of respondents - categorical	Survey result
Var 5: "Ethnicity"	Ethnicity of respondents - categorical	Survey result
Var 6: "Residency"	Current residency - categorical	Survey result
Var 7: "Downtown"	Frequency visiting downtown - categorical	Survey result
Var 8: "NewYork"	Visited New York - categorical	Survey result
Var 9: "TreeImpacts"	Comments about tree impacts on urban objects - categorical	Survey result

Table 3-8. Categories of independent variables.

Variable Name	Description of Variable	Source
Distance	Distance away from the building in each photo - numerical	Measurement from Google Earth
Age	Age of respondents – categorical Category 1: 18 - 24 Category 2: 25 - 34 Category 3: 35 - 44 Category 4: 45 - 54 Category 5: 55 - 64 Category 6: 65 and over	Survey result
Gender	Gender of respondents – categorical Category 1: Male Category 2: Female	Survey result
Education	Education attainment of respondents – categorical Category 1: Did not complete high school Category 2: High school / GED Category 3: Some college Category 4: Bachelor's degree Category 5: Master's degree Category 6: Doctoral degree or post-doctoral degree Category 7: Professional degree (M.D., J.D.)	Survey result
Ethnicity	Ethnicity of respondents – categorical Category 1: American Indian / Native American Category 2: Asian / Pacific Islander Category 3: Black / African American Category 4: Hispanic / Latino Category 5: White / Caucasian Category 6: Other	Survey result
Residency	Current residency – categorical Category 1: Urban area in the United States Category 2: Suburban area in the United States Category 3: Rural area in the United States Category 4: Urban area outside of the United States Category 5: Suburban area outside of the United States Category 6: Rural areas outside of the United States	Survey result
Downtown	Frequency visiting downtown – categorical Category 1: Everyday Category 2: Few times a week Category 3: Few times a month Category 4: Few times a year Category 5: Once in few years Category 6: Less than 3 times in the past 10 years Category 7: Never	Survey result
New York	Visited New York before – categorical Category 1: Yes Category 2: No	Survey result
TreeImpact	Comments about tree impacts on urban objects – categorical “Do you think city trees have impacts on object visibility and recognizability in an urban environment?” Category 1: Yes Category 2: No	Survey result

3.5.2 Multicollinearity testing of socio-demographic variables

As Appleyard (1969) emphasizes the need to examine intercorrelation among independent variables, the multicollinearity statistics are tested in this study among socio-demographic variable to prevent severe multicollinearity in the regression analysis. Multicollinearity exists *"when two or more independent variables in the model are approximately determined by a linear combination of other independent variables in the model"*[7]. If there is a severe multicollinearity, the standard errors for the coefficients are inflated. As a result, the estimated binary logistic regression coefficients are unreliable.

It is generally accepted that the two common measures of multicollinearity are tolerance and Variance Inflation Factor (VIF). VIF values indicate how much the multicollinearity among variables causes the inflation of the standard error. If the VIF values of one or two socio-demographic variables are higher than the accepted range, that particular variables have to be excluded from the regression analysis.

3.5.3 Statistical procedures

After the multicollinearity test is performed, all valid independent variables and the dependent variables are imported into SPSS statistical software for recognizability analysis. The goal of the statistical analysis is to investigate what factors predict the correct building RC. The dependent variable of this quantitative analysis is the RC. The RC shows the accuracy of survey participants responses to the photo question. RC is binary data with only two values: "correct" or

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[7] https://stats.idre.ucla.edu/stata/webbooks/logistic/chapter3/lesson-3-logistic-regression-diagnostics

"incorrect". There are 11 independent variables which include 8 socio-demographic variables in table3-6, Green Ratio, and number of building in each photo.

Dai and Lee (2003) suggest that *"logistic regression modelling has proved to be useful in examining the relationship between a set of independent variables and a dependent variable that takes only two dichotomous values."* As the dependent variable RC is binary data with dichotomous values, a binary logistic regression seems to be a good statistical tool for this study. The objective of using binary logistic regression is to find the best fit model to describe the relationship between the dichotomous dependent variable RC and a set of independent variables (as predictors). The equation for the dependent variable and the independent variables is illustrated below (Menard, 1995):

$$logit\ (Y) = \alpha + \beta_1 X_1 + \cdots\cdots + \beta_n X_n$$

where $\beta_i (i = 1, \cdots\cdots, n)$ is the estimated coefficient; α is the intercept. This model predicts the odds ratios that the likelihood of one outcome (correct RC) will occur. The relationship between RC and independent variables is non-linear in the logistic regression model, an iterative algorithm is necessary for parameter estimation (Dai and Lee, 2003).

The final complied database has the dependent variable RC and other 11 potential independent variables. As mentioned in the earlier section, some variables may need to be excluded from the analysis if strong multi-collinearity exists. The complied database consists of 3,492 records (97 participants x 36 photos). Each record has the RC of every photo that the participant evaluated. The result of this binary logistic regression will be presented in the next chapter.

CHAPTER 4

RESULTS AND DISCUSSION

In previous chapter, the procedures of establishing online survey and corresponding statistical analysis are discussed. The respondent's correctness (RC) records how respondents of the survey correctly or incorrectly identify the number of buildings in each photo.

4.1 Survey result

Among all 97 collected responses, the Respondent's Correctness of each building is illustrated in table 4-1 and figure 4-1.

Table 4-1. Respondent's correctness (RC) – how respondents correctly or incorrectly identify the number of buildings in each photo of this survey.

		Respondents' correctness		
		Correct	Incorrect	Total
Building	CF	27	70	97
	BF	73	24	97
	Bryant	69	28	97
	Fitterman	74	23	97
	DPM	43	54	97
	River T	81	16	97
	Foley	58	39	97
	Herald	68	29	97
	San Remo	75	22	97
	UN	25	72	97
	Majestic	83	14	97
	PC	74	23	97
Total		750	414	1164

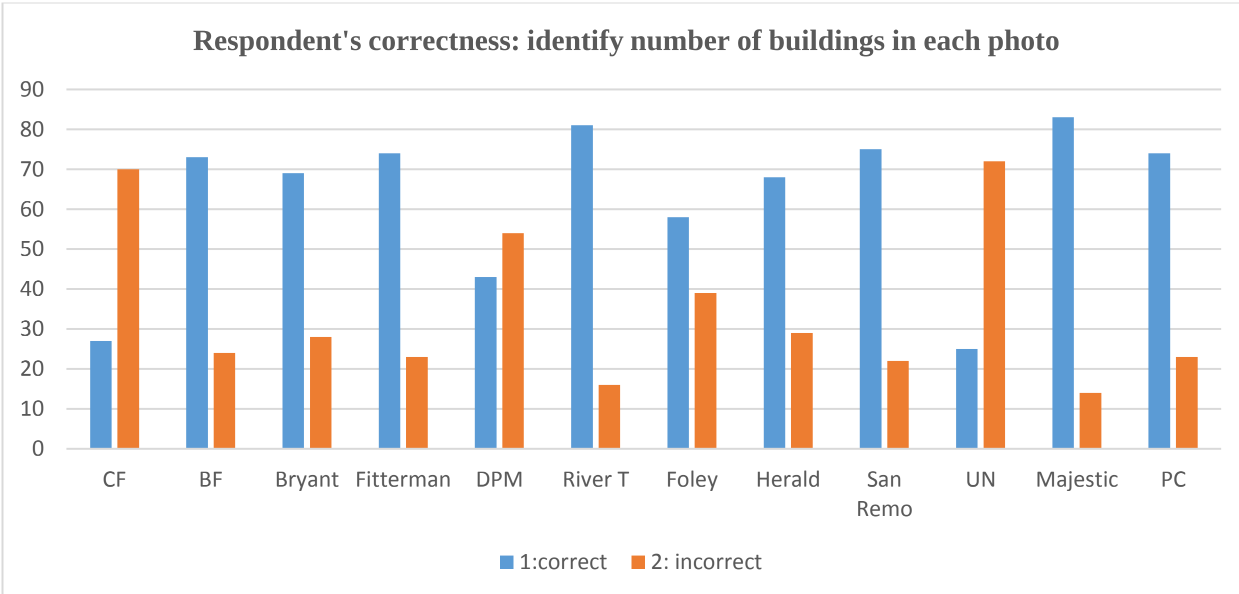


Figure 4-1. Histogram of respondent's correctness of each building.

The RC cannot be explained explicitly without further exploring the corresponding independent variables of the database. Figure 4-2 to 4-9 below illustrates the socio-demographic characteristics of respondents. Age is the first socio-demographic independent variable of the analysis. It is assumed that different age groups of people may perceive the urban space differently (Appleyard, 1969). According to table 4-2, there are about one-third of respondents who are in the age group of 25-34 years old while the second largest group of respondents comes from an age group of 35-44 years old. There are 10 senior respondents with 65 years old or above participating in this survey.

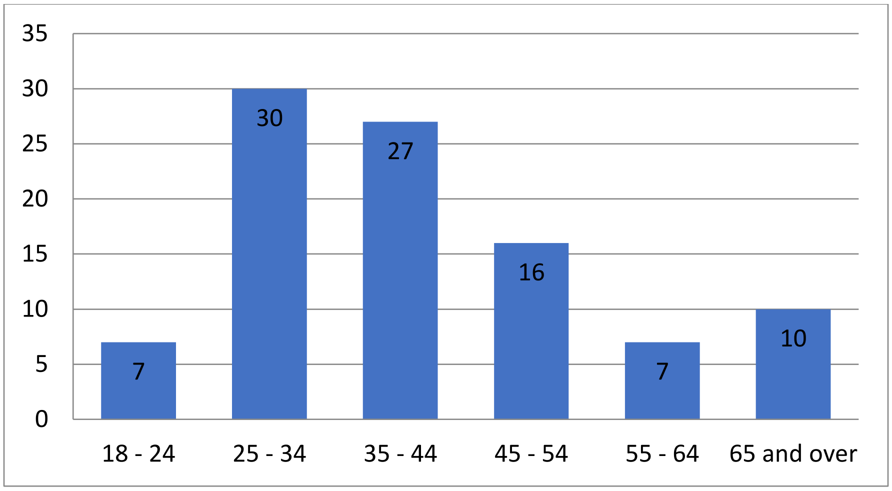


Figure 4-2. Age distribution of respondents.

The gender ratio is quite balanced in this survey as there are 55 female respondents and 44 male respondents (figure 4-3). Reilly et al. (2017) attempted to investigate the existence of gender difference in spatial ability or “visual-spatial ability”. They define the spatial ability as “the ability to perceive and understand spatial relationships, to visualize spatial stimuli such as objects, and to manipulate or transform them in some way...” (Reilly et al., 2017).They suggested that males on average outperform females in spatial tasks. It is critical to include the gender question in the survey to further examine how gender may or may not influence the RC.

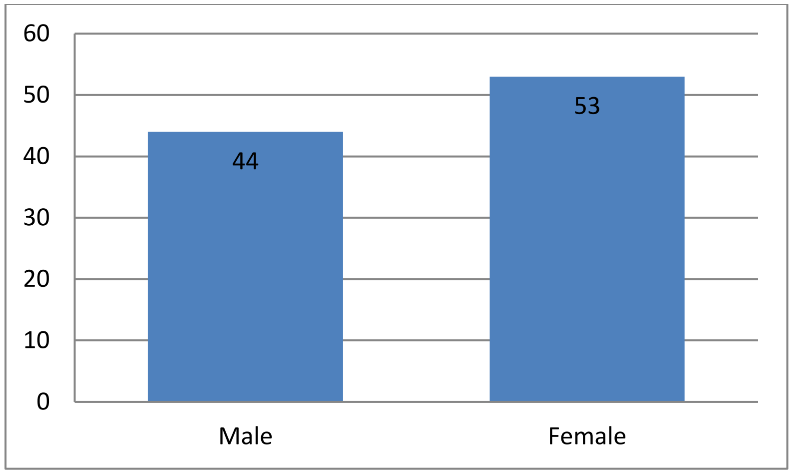


Figure 4-3. Gender distribution of respondents.

Reilly et al. in fact explore the spatial ability among males and females in different academic majors and level. They specifically investigate the variation of spatial ability in STEM students. In this study, the survey includes a variable of education attainment of investigate if level of education increases or decreases the recognition accuracy of target building in each photo. About half of the respondents obtained a doctoral degree or post-doctoral degree (figure 4-4). This distribution makes sense because the respondents are from the American Association of Geographers whom may have already obtained doctoral degree in academia. There are 15 respondents with no bachelor degrees. The distribution of the education level is not fully-biased.

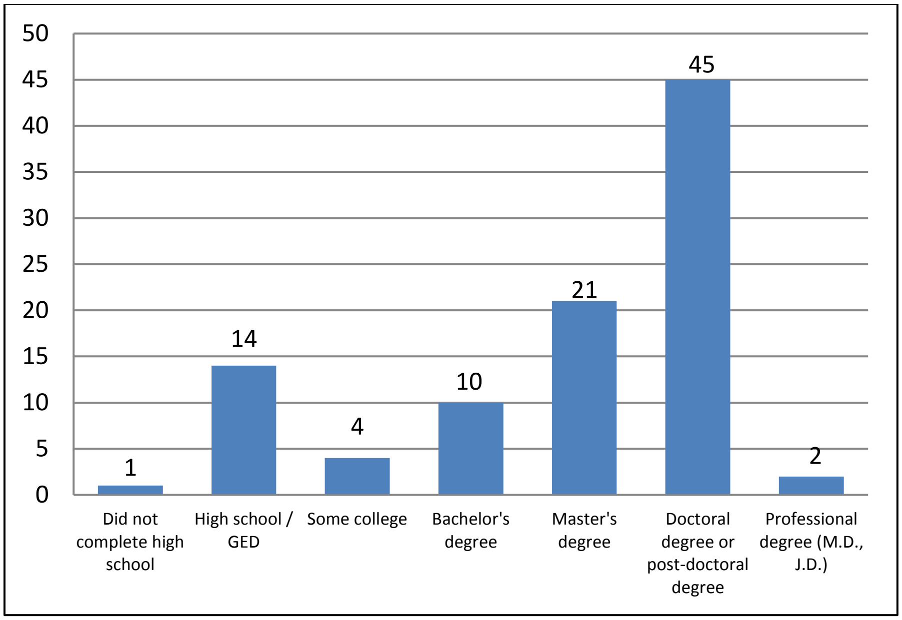


Figure 4-4. Highest education attainment of respondents.

About half of the respondents are white while 29% of respondents are from Asian or Pacific Islander origin (figure 4-5). Janssen and Geiser (2012) suggest that Germans adapted a holistic strategy on spatial ability test while Cambodians used analytic strategies. Their research gives an insight that different ethnic groups may use different strategies to solve spatial problems. When the recognition problem of buildings arises, ethnicity may be a factor influencing the respondent's choice of answer in photo questions in this survey.

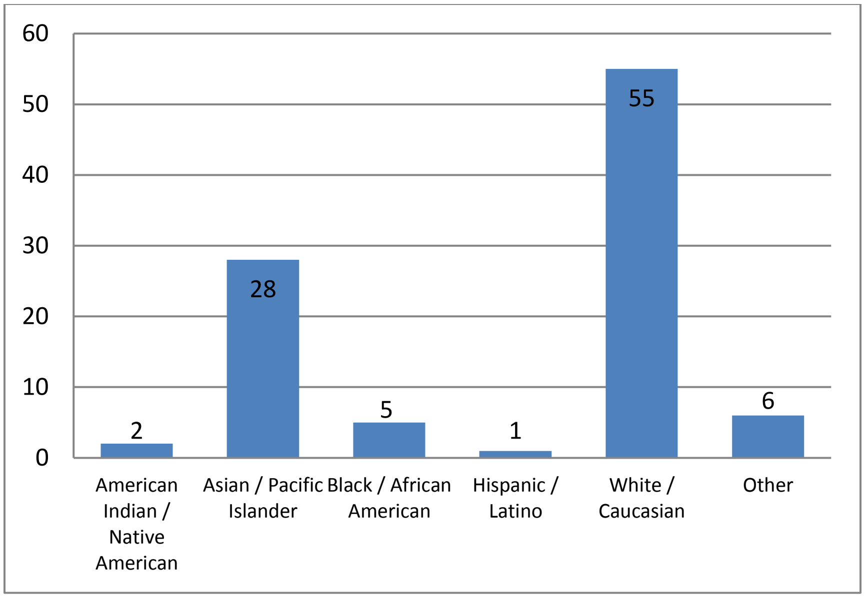


Figure 4-5. Ethnicity of respondents.

Questions regarding residency and downtown visits yield interesting results. A majority of respondents currently live in urban areas within or outside the United States. 69 respondents are from the urban areas (figure 4-6). There are about 36% of respondents visiting downtown areas daily (figure 4-7). A high percentage (72% of respondent) has visited New York before (figure 4-8). Scholars in general agree that inhabitants who have regular connection and interaction with urban areas have a stronger visual perception and memories of urban objects (Heath, 2000; Nasar et al, 1999; Nasar et al., 2001; Chang et al., 2018; Appleyard, 1969). It is vital to include the variables about current residency, downtown visit frequency, and past visitation to New York in this survey. It is assumed that a person who frequently visits New York City may have stronger visual memories towards the streetscape in Manhattan. This person can be assumed to possess higher accuracy in recognizing the correct number of buildings among photos. But the assumption is not valid until the result of the survey is tested in a statistical analysis.

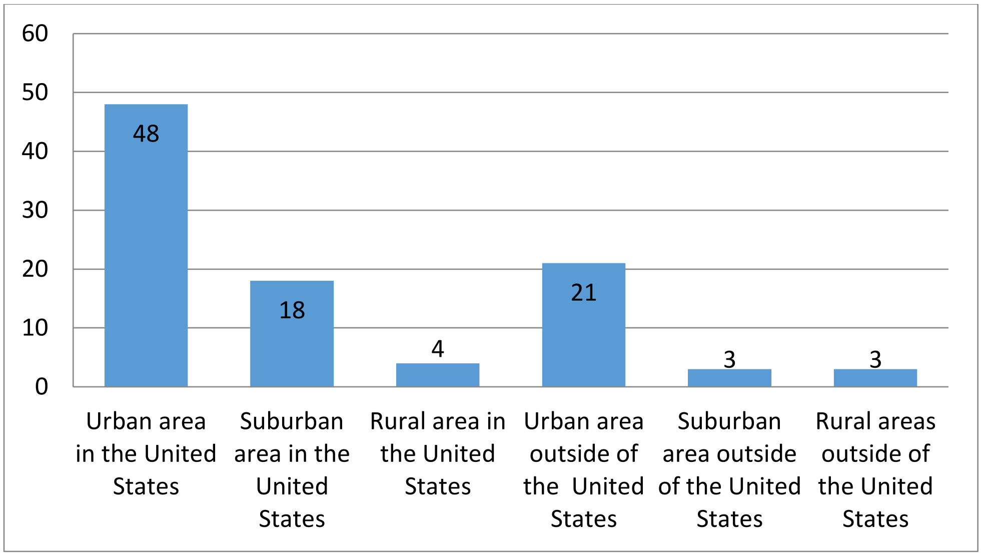


Figure 4-6. Current residency of respondents.

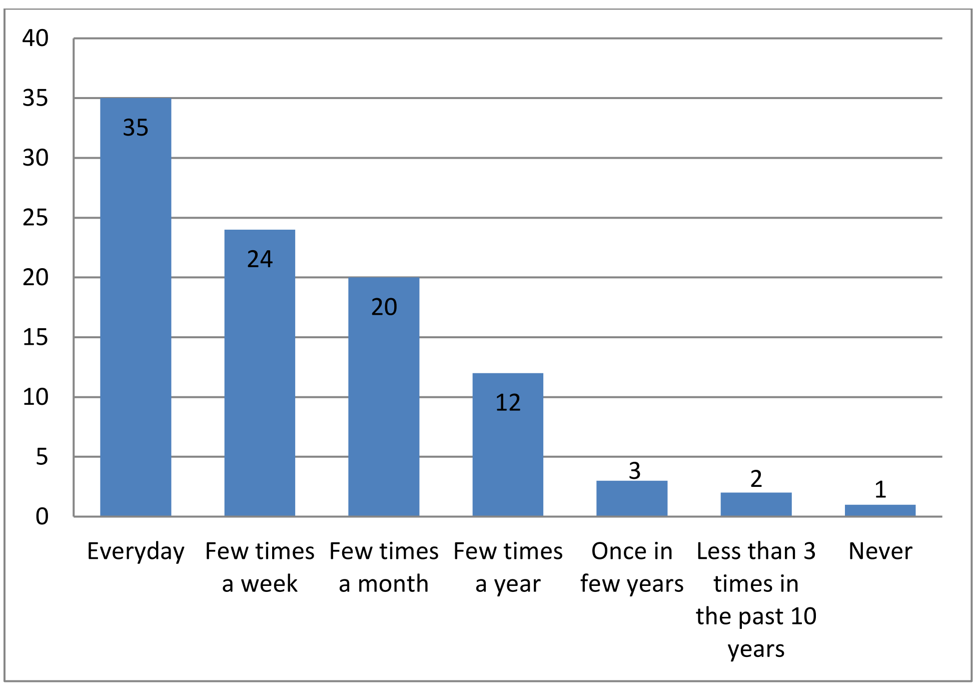


Figure 4-7. Frequency of downtown visits of respondents.

Among all respondents, 76 people agreed that trees have impacts on the recognizability of urban objects (figure 4-9). A loose assumption can be made to explain that if a respondent agrees with tree impacts on recognizability, he or she may focus more on how tree obstructs the target building with a more prudent guess.

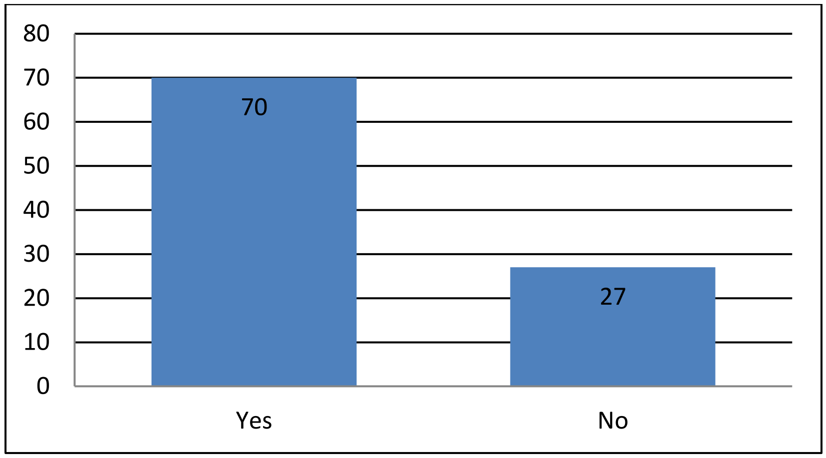


Figure 4-8. Statistics showing whether the respondents visited New York before.

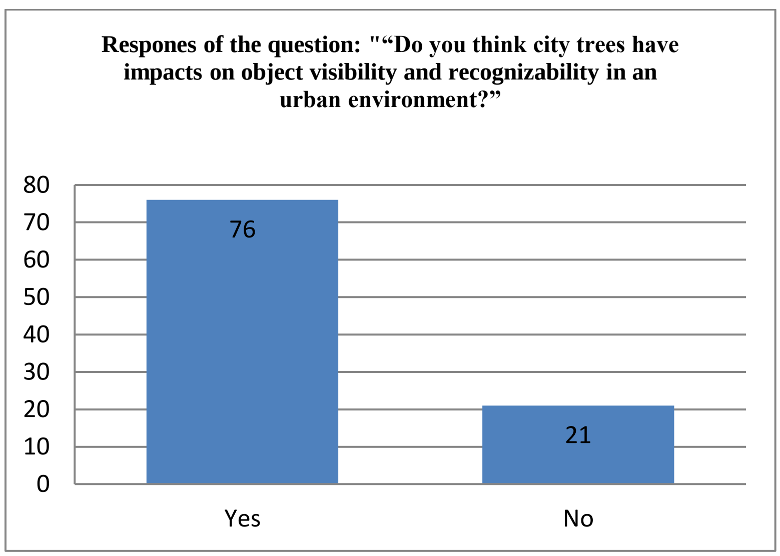


Figure 4-9. Statistics showing responses to this question: “Do you think city trees have impacts on object visibility and recognizability in an urban environment?”

The survey results provide an important data source to test above the above assumptions to examine whether socio-demographic factors of respondents influence their recognition accuracy upon urban buildings. It is fair to assume to that a middle-aged male respondent with a doctoral degree who currently lives and works in New York City, may identify the number of buildings in each photo with higher accuracy. The relationship between the RC and socio-demographic variables needs to be tested in a statistical analysis in order to examine whether the assumption is valid. Some socio-demographic variables may have more significant influence on the RC over the other. While there is no existing research to study such relationships between the building recognition and respondent's socio-demographic characteristics in the realm of geospatial information science, this study provides the first attempt to perform statistical analysis on all variables in a regression model, the results will be explained in the next section.

4.2 Statistical Analysis

Eight Socio-demographic variables and other two independent variables are included in the logistic regression model of the RC. The other two non-sociodemograhic independent variables are Green Ratio and Distance. First, in a logistic regression model, it assumes a linear relationship between the logit and the continuous covariate (Elswick et al., 1997). When the relationship between the two is not linear, the transformations of the covariate can be applied to satisfy the linearity assumption. In the dataset for this study, variables of Green Ratio and Distance need to be transformed to fit the assumption of linearity.

Overdispersion occurs where the residual deviance is much greater than the residual degrees of freedom[8]. Table 4-2 demonstrates there is no overdispersion problem of the data as the dispersion parameter is close to 1. Multicollinearity does not exist between the variables and all variables are acceptable to be included in the regression analysis.

The dependent variable RC and all independent variables are entered into the quasi-binomial logistic regression model. Table 4-2 shows the final result of the regression analysis. The goal of this regression analysis is to search for the best fit model to describe the relationship between the dependent variable RC and a set of independent variables (as predictors).

From the result, it is evident that the log-transformed Distance variable and the log-transformed Green Ratio variable are significant under the significance level of 0.001. RCs of buildings including Bryant, Fitterman, Peter Copper Village, River Terrace, San Remo, and U.N. are all significant. Downtown Visit variable (i.e. few times a week) is significant under the 0.01

[8] http://www.mun.ca/biology/dschneider/b7932/B7932Final4Mar2008.pdf

significance level. Downtown Visit variable (i.e. few times a month) yields significant result under the 0.05 significance level. We can reject the null hypothesis which states that, the coefficients associated with the variables is equal to zero. In other words, there exists a relationship between the independent variable RC and these dependent variables.

The result from this regression model suggests that the demographic variables including age, sex, education, and ethnicity do not significantly predict RC. The only social variable (Downtown visits) appeared to be a significant predictor in the model. The other significant variables are non-sociodemographic variables. This particular scenario can be explained in a twofold manner. First, the social variables embed with visual experiences and memories. For instance, a daily visitation to downtown enhances visual memories to the surrounding environment. The urban spatial configuration can be more familiar to the respondents who go to downtown every day. Second, the significance of variables of Green Ratio and Distance suggest topological relation between building and vegetation is important in shaping the recognizability. And the topological relation varies in the view of an observer from different distances. The following section will explain the two outcomes in detail.

Table 4-2 The result of regression model

	Estimate	Std. Error	t value	Pr(>|t|)	
(Intercept)	4.13267	0.93547	4.418	1.09E-05	***
lnDistance	-0.66491	0.13206	-5.035	5.56E-07	***
lnGreenRatio	-0.10374	0.03489	-2.974	0.003005	**
Building - Bryant	-1.86372	0.23478	-7.938	4.93E-15	***
Building -CF Plaza	0.19423	0.22846	0.85	0.395423	
Building -DPM	0.15923	0.24048	0.662	0.508021	
Building -Fitterman	-1.3248	0.23028	-5.753	1.13E-08	***
Building -Foley	0.25045	0.25037	1	0.317374	
Building -Herald	0.39186	0.21622	-1.812	0.070201	.
Building -Majestic	0.268	0.23587	1.136	0.256109	
Building -PC	1.9991	0.33001	6.058	1.88E-09	***
Building -River Terrace	0.65559	0.24409	2.686	0.007341	**
Building -San Remo	1.04892	0.27113	3.869	0.000116	***
Building -UN	0.97566	0.2483	3.929	9.04E-05	***
Gender- Female	0.11368	0.16721	-0.68	0.496719	
Education - High School	0.48336	0.73994	0.653	0.513735	
Education- Some college	0.24685	0.30129	-0.819	0.412782	
Education- Bachelor	0.13697	0.38743	-0.354	0.723753	
Education- Master	0.02714	0.25604	-0.106	0.915589	
Education-Doctoral or post-doc	0.07084	0.21879	0.324	0.746151	
Education- M.D/J.D	0.03237	0.20087	-0.161	0.87201	
Ethnicity - Asian/Pacific Islander	0.05248	0.62959	-0.083	0.933584	
Ethnicity- Black/African American	0.04953	0.70085	-0.071	0.943668	
Ethnicity - Hispanic/ Latino	0.83037	0.99873	0.831	0.40591	
Ethnicity - White/ Caucasian	0.32591	0.62878	0.518	0.604333	
Ethnicity - Other	0.01969	0.67057	-0.029	0.976577	
Residency - Suburban in U.S.	0.29003	0.20546	-1.412	0.158352	
Residency - Rural in U.S.	0.11663	0.23432	-0.498	0.618775	
Residency - Urban outside U.S.	0.65344	0.37702	-1.733	0.083338	.
Residency - Suburban outside U.S.	0.26382	0.23338	1.13	0.258527	
Residency - Rural outside U.S.	0.25104	0.39232	-0.64	0.522384	

Table 4-2 The result of regression model (continued).

	Estimate	Std. Error	t value	Pr(>|t|)	
DowntownVisit - Few times a week	0.61736	0.2294	2.691	0.007226	**
DowntownVisit- Few times a month	0.55162	0.26056	2.117	0.034477	*
DowntownVisit - Few times a year	0.30257	0.25777	1.174	0.240712	
DowntownVisit - Once in few years	0.43067	0.32959	1.307	0.19159	
DowntownVisit < 3 times in past 10 years	0.0733	0.50098	0.146	0.883695	
DowntownVisit - Never	0.63835	0.52468	-1.217	0.223995	
NewYork- No Visit Before	0.05971	0.22176	0.269	0.787795	
TreeImpact - No impact	0.07007	0.18378	0.381	0.70307	

Overdispersion	1.043495

4.2.1 Recognizability , Green Ratio, and Distance

The regression model suggests that the log-transformed Green Ratio is significant in predicting the recognizability. In other words, a 10-fold increase in Green Ratio will have the effect on the odds ratio. According to figure 4-1, Confucius Plaza, D.P. M. Courthouse and the United Nation building yields more incorrect RC responses than correct. The Green Ratio of these buildings can be examined to investigate deeper relationships between incorrect recognizability and surrounding vegetation.

Figure 4-10 shows the photos of CF Plaza from close, medium, and far viewing distances. In the far distance photo, there is no vegetation presented in that highlight region. Vegetation is also not present in the highlighted region in the close-range photos of DPM Courthouse and UN Building (figure 4-11 and 4-12). The recognizability of the buildings from those 3 photos should be high. However, the recognizability of those three buildings is empirically low from the survey result. To better explain this result, the topologic relation of vegetation with the buildings needs to be studied. The topologic relation of vegetation relates to the arrangement of vegetation in relation to the façade of the building. The Green Ratio is able to show the presence of vegetation at each location. If the vegetation concentrated in a location where foliage and canopies block building façades significantly, the recognizability can be low. The far-distance photo of the UN building is a good example. The Green Ratio is 36 % which proves that at least one-third of the highlighted region is covered by vegetation. But there is a key question to ask: which part of the building is covered by vegetation?

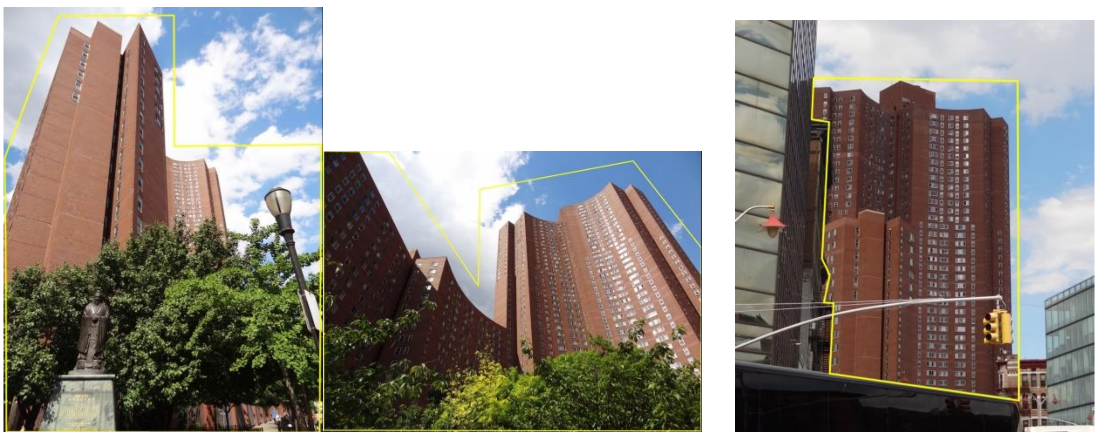


Figure 4-10 . Photos of CF Plaza (from left to right: close, medium, and far distance).

Figure 4-11. Photos of D.P.M. Courthouse(from left to right: close, medium, and far distance).

Figure 4-12. Photos of UN Building(from left to right: close, medium, and far distance).

In order to provide the answer to the question “which part of building is covered by vegetation and hence reducing recognizability?”, the viewing distance of the building has to be considered. The result of the regression model suggests the variable distance can be a predictor of recognizability. The UN building again can provide a good explanation to this. From the right photo of figure 4-12, vegetation blocks the bottom part of the UN building in the far-distance photo. When an observer moves closer to the building in the mid-viewing-range, more building façade is exposed. The building structure with two towers and a shared-base is clearly shown to an observer in the near range. In short, the recognizability of the building can be the highest because an observer can see the building structure clearly from a near ground level without any obstruction of vegetation.

In the case of New York City, vegetation often is present in the medium-viewing-range area such as road median dividers, urban parks, or pedestrian pathways. The recognizability of the medium-viewing-range photos of the above 3 locale are low. That suggests the moderately high presence of vegetation in the medium viewing distance contribute to the low recognizability of buildings. Among all 12 buildings, the Majestic Apartment building is located near Central Park (figure 4-13). A thick presence of trees is situated along the line of sight in figure 4-13. This is another good example demonstrating how vegetation even at far-distance can influence recognizability of a building.

4.2.2 Recognizability and building structure

The result of our regression model suggests that the coefficients of building Bryant, Fitterman, PC, River Terrace, San Remo and U.N. are different from the grand mean significantly. The probability of having correct RC is lower for Bryant and Fitterman building while the coefficients for both buildings are negative. The probability of having correct RC is higher for PC, River Terrace, San Remo and U.N. building. All 6 buildings share a commonality – they all have connected multiple towers or multiple building structure parts (figure 4-13 and 4-14) . Heath et al. (2000) suggests the shape of the building can influence visual complexity. Scholars agree that the physical attributes of a building shape the corresponding aesthetic quality in a city (Nasar, 2001; Stamps, 2002; Zacharias, 1999). From the result of the analysis of this study, it is evident that the physical form of the building can influence recognizability. If the towers are visible but the base part of the building is obstructed by vegetation, an observer can mistakenly recognize this building as two separate buildings. The visible towers at the top and blocking vegetation near the group confuse the visual judgement of an observer. This kind of misjudgment occurs in all of these 6 buildings.

As shown in figure 4-13 (a), a crucial part of Bryant Building is blocked by the New York Public Library. The complete building structure is not visible to an observer from this particular distance. This can diminish the recognizability as well. It is nearly infeasible to see the complete structure of entire tower because of its location in the mid-town of Manhattan. The streets are narrow and buildings are close to each other. The visual threshold for this building is limited by dense surrounding buildings.

Another physical attribute that is worthy of investigation is the proportion of towers and the shared-base of particular buildings. Figure 4-14 (c) illustrates the tall towers and flat share-base of UN building. There are about 6 floors for the shared-base. The towers above the shared-base are much taller. In other words, the flat shared-base can be easily obstructed by ground vegetation. In a short conclusion, the recognizability of a building can reach maximum if an observer is close enough to the building where there is no obstruction of vegetation blocking the building façade. This situation applies to River Terrace and San Remo building as well. The probability of having correct RC is high for Peter Copper Village (figure 4-13 (c)).

Figure 4-13 (a) to (c): Left to right: Bryant, Fitterman Hall, and PC.

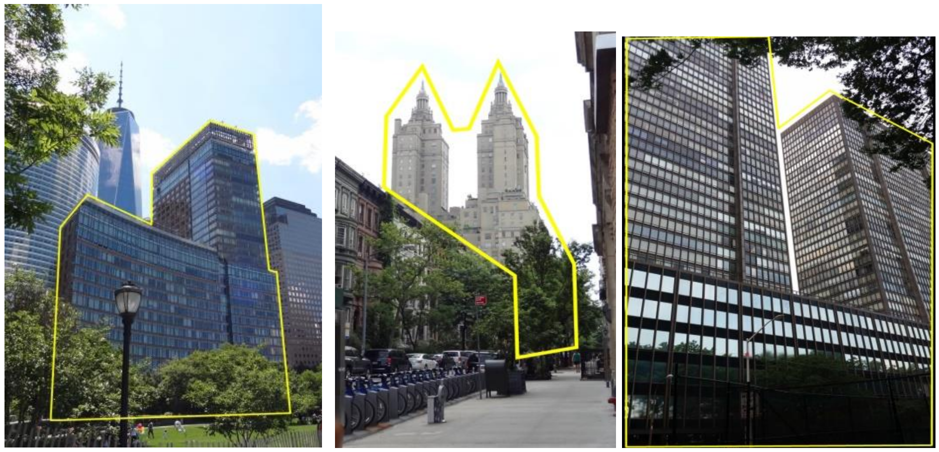


Figure 4-14(a) to (c): Left to right: River Terrace, San Remo Apartment, and UN Building

The figure 4-13c clearly shows the big seperation or gap between buildings. It is evident that the existing wide gap between buildings can yield high RC at this locale. The structure of two buildings in figure 4-13 (c) is clearly shown from this viewing angle and distance.

Buildings with significant results in the regression model all have complex silhouette. In figure 4-14 (a) to (c), all buildings have multiple towers and share-base. Heath et al. (2000) assume that the perceived complexity of tall buildings from a distance depends on three variables: the umber of elements, the asymmetry of shape, and the asymmetry of arrangement. The result of this dissertation seems to echo with the suggestion proposed by Heath et al. (2000). The recognizability of buildings seems to have the significant relationship with the correpsonding complex building structure.

4.2.3 Recognizability and frequency of downtown visits

According to Appleyard (1969), the urban knowledge of a person is supplemented by the visible and distinctive elements encountered in more frequent travels within the city. Another element of urban knowledge is about the usage of the urban object. If a person uses the object more frequently such as working in that particular office building or dining in one same shopping mall, the urban knowledge about the object increases. The result of the logistic model seems to with Appleyard's point. If a person has frequent visits to a downtown area, the person accumulates urban knowledge temporally and quantitatively. Other physical attributes of urban buildings such as colors, windows, building materials, and roof lines are familiar elements to this person. If the towers consist of different colors and windows, this person may be able to quickly judge the towers in fact come from two separate buildings. But if two towers share same color and architecture design, the strong urban knowledge can help the person to evaluate correctly that the towers belong to one single building. Frequent visits to downtown areas can increase urban knowledge; and hence, increase the accuracy of visual recognition of urban objects.

CHAPTER 5

CONCLUSION

Urban landscape elements, such as the topological relations between spatial objects, spatial configuration of the city, and visual observation of spatial objects, create the image of a city (Lynch, 1960; Appleyard, 1969; Heath & Smith, 2000). The image of a city is essential for city planners and urban designers. Steinitz (1967) suggests that city images coordinate form, visibility, and action with community significance to create a more meaningful city. A meaningful city aims to benefit citizens and inhabitants who dwell in the city. A good predictive tool to reflect the population‘s perception of the urban objects is vital in creating more personalized city designs.

As more “green” cities are emerging in the 21st century (The World Economic Forum, 2018), human recognition of urban buildings can be obstructed by increasing amount of vegetation in urban areas. While the architectural designs of urban buildings are more complicated than before, architects often seek the maximum exposure of the design to general public. The complexity of building structure actually captures inhabitants attention (Heath et al., 2000). If vegetation obstructs significant portions of an innovative design of a building, the visual value and attractiveness of the building can diminish greatly. People may not able to retain much visual and spatial memories about a building or even a city because their views are obstructed. Eventually, the building loses its ability to covey the uniqueness to general public.

On the other hand, people choose to use a recognizable urban object or landmark to navigate (Lynch, 1960; Appleyard, 1969; Mark et al., 1999). Building obstruction by vegetation can significantly influence how people navigate among the concrete jungle. After all, it is essential to understand how buildings are recognized in a city to generate a better urban spatial configuration. Predicting visual recognition of buildings can bring benefits to urban designers, architects, city planners, landscapers, and city promoters.

Unfortunately, no existing studies have made attempts to explore the methods of predicting visual recognition of buildings in an urban environment. A considerable number of scholarly works devoted to visibility analysis (Bartie et al., 2011; Yin et al., 2012; Fisher et al., 1997), as yet no research the author is aware of has addressed visual recognition or recognizability of urban buildings from the perspective of geospatial information science.

This research demonstrates a quantitative approach to predict factors that influence visual recognition or recognizability of buildings in an urban environment. The research questions can be answered from a statistical and spatial perspective. First, recognizability of the buildings is quantified by the values of RC. The values are computed from the result of a quantitative survey. 97 participants evaluated 36 field photos from New York City and each participant identified the number of buildings in each photo. RC values reflect the accuracy of how participant recognizes the correct number of building. Participants of the survey are asked to answer 8 socio-demographic questions. The results of the survey demonstrate some buildings yield higher recognition accuracy but some do not. This result inspires a further investigation of the relationship between the building, participant's characteristics, and RC. A regression analysis is performed to examine this relationship.

In order to further explore how vegetation influences the recognizability of buildings; a Green Ratio is generated for each photo. The Green Ratio calculates the ratio of obstructed vegetation to the nearby building. The regression analysis aims to study if distance, Green Ratio, age, sex, gender, ethnicity, education, residency, frequency of downtown visits, previous New York City visits, and opinions about urban recognizability can serve as predictors the RC.

The results of regression analysis suggest that distance, green ratio, frequent downtown visits are significant factors in predicting visual recognition or recognizability of buildings. Moreover, the physical and topologic form of buildings contributes effects on the recognizability. The recognizability of a building can reach maximum if an observer is located close enough to the building where there is no obstruction of vegetation blocking the building façade along his line of sight. Another critical factor of predicting visual recognition of buildings is related to the physical structural form. If a building consists of two or multiple towers and a shared-base, recognition can be low if the vegetation blocks the base floors. The towers of the building can confuse visual recognition of people as the two towers appear as two separate buildings from a medium or far viewing distance.

This research is not to provide an exhaustive and advanced regression model; instead, presenting a preliminary method from a statistical and spatial perspective to investigate visual recognition or recognizability of urban buildings. The result can be beneficial to urban planners, architects, city planners, urban geographers, and city tourism broads for better integration of vegetation and buildings in a cityscape. The ultimate goal of understanding people's visual recognition and perception of urban objects is to raise inhabitant's satisfaction, capture their attention, and make strong impressions of the city.

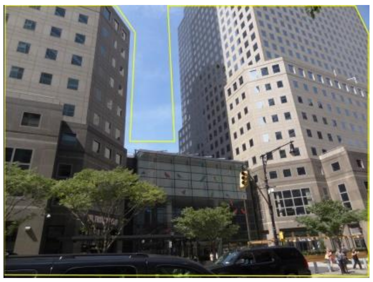
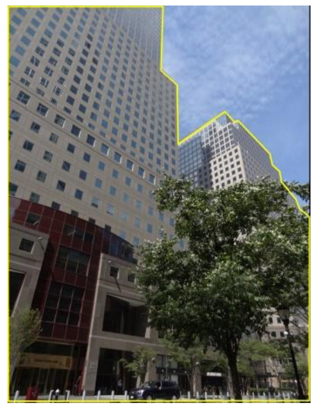
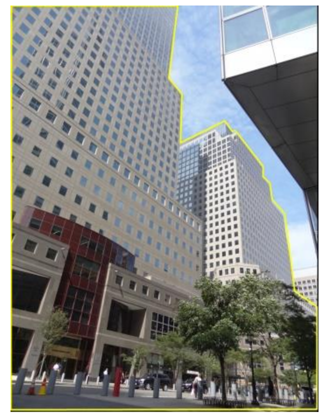
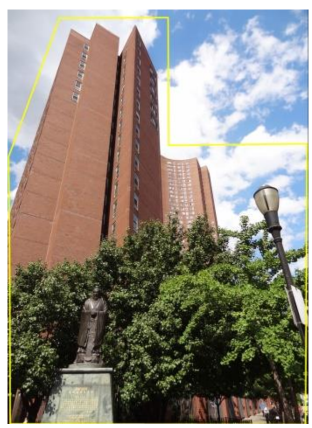
The application of the research method of this study can extend to non-urban environments. Recognizability of geological features is vital in the field of geosciences. One can further study the factor of predicting recognizability of a rural geological feature by adopting the quantitative method this dissertation suggests.

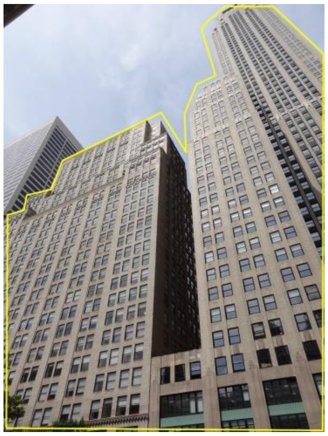
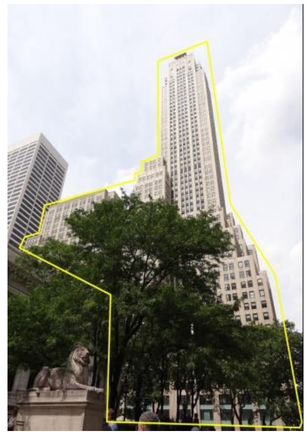
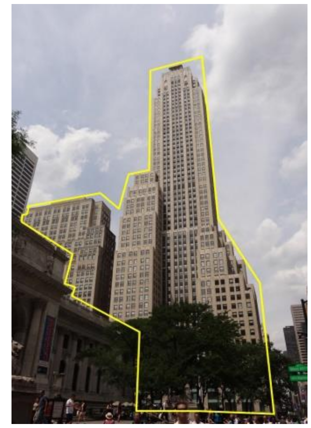
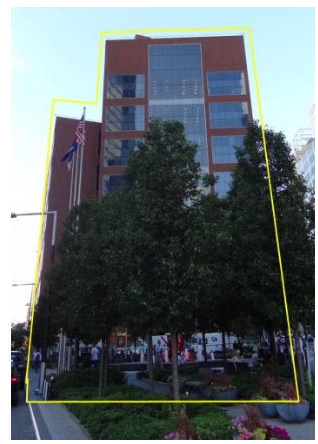
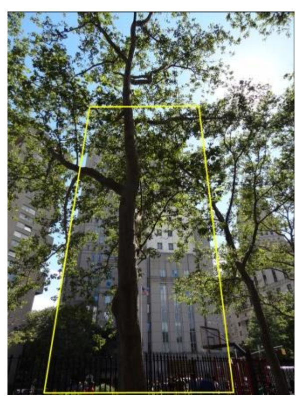
This dissertation is a preliminary study related to recognizability of urban buildings. Some limitations and challenges are expected to be found. First, the data collection was a challenging process because the process was limited by time. Some locales were difficult to access due to construction, narrow pathways, safety issues, or traffic. As a result, the field photos cannot be taken with standardized viewing distance and angles. Second, the results of the survey are highly subjected to personal preferences, experiences, and background. A survey with larger sample size may be beneficial to offer a more robust result. Third, the recognizability is quantified by the RC value in this study. Recognizability can be defined and quantified in other ways.

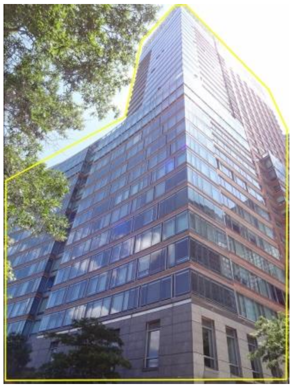
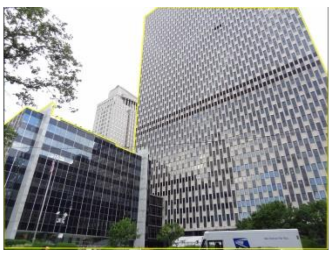
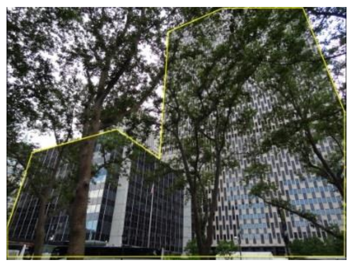
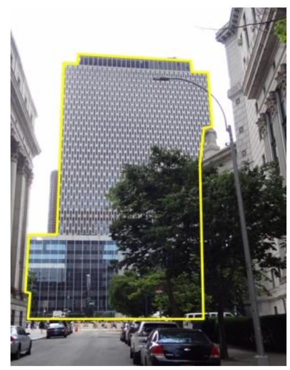
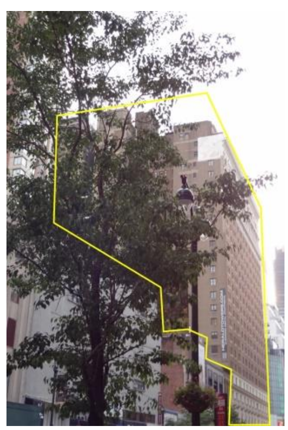
Despite these limitations, the approaches developed in this paper serve the purpose of investigating spatial relationships between recognizability of urban buildings, distance, vegetation, and socio-demographic factors from a statistical and spatial perspective. The results presented here provide a starting point for further research in the development of a more sophisticated GIS model to predict and map the recognizability of spatial objects.

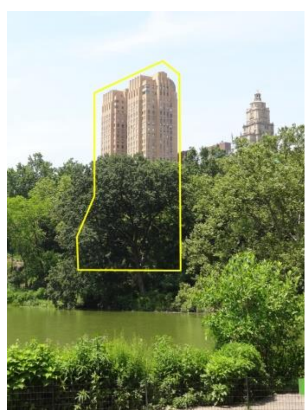
APPENDIX A

PHOTO INVENTORY FOR SURVEY: 36 FIELD PHOTOS

	Close Range	**Mid Range**	**Far Range**
BF Place			
CF Plaza			

Bryant			
Fitter- man			
DPM			

River Terrace			
Foley Square			
Herald Tower			

San Remo			
UN			
Majestic			

Peter Copper Village			

APPENDIX B

SURVEY QUESTIONS ABOUT DEMOGRAPHIC INFORMATION

Q1. What is your age?

- 18 - 24
- 25 - 34
- 35 - 44
- 45 - 54
- 55 - 64
- 65 and over

Q2. What is your gender?

- Male
- Female

Q3. What is the highest level of education you completed?

- Did not complete high school
- High school / GED
- Some college
- Bachelor's degree
- Master's degree
- Doctoral degree or post-doctoral degree
- Professional degree (M.D., J.D.)

Q4.What is your ethnicity?

- American Indian / Native American
- Asian / Pacific Islander
- Black / African American
- Hispanic / Latino
- White / Caucasian
- Other

Q5. Where do you live now?

- Urban area in the United States
- Suburban area in the United States
- Rural area in the United States
- Urban area outside of the United States
- Suburban area outside of the United States
- Rural areas outside of the United States

Q6. How often do you go to the downtown/metropolitan area near your current place of residence?

- Everyday
- Few times a week
- Few times a month
- Few times a year
- Once in few years

- Less than 3 times in the past 10 years
- Never

Q7. How frequent have you been to New York City, United States?

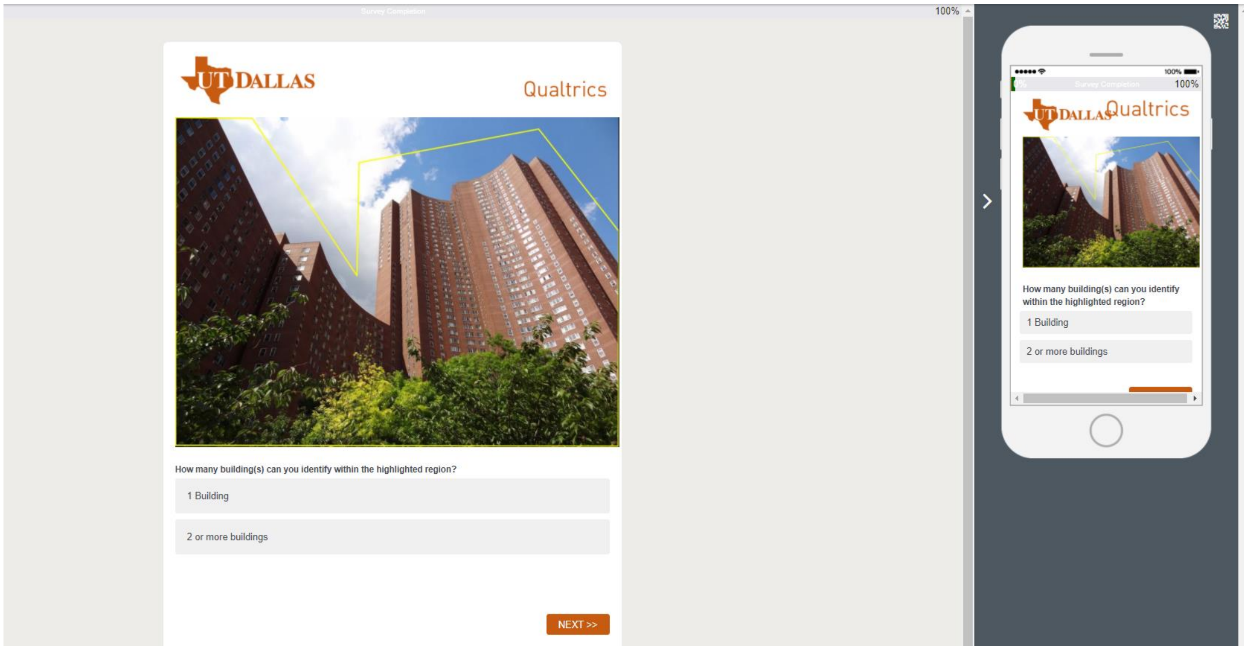
- Everyday
- Few times a week
- Few times a month
- Few times a year
- Once in few years
- Less than 3 times in the past 10 years
- Never

Q8. Do you think city trees have impacts on object visibility and recognizability in an urban environment?

- Yes
- No

APPENDIX C

THE FRONT PAGE OF THE SURVEY WEBSITE



The URL to the survey:

https://utdallas.qualtrics.com/jfe/form/SV_1TaFshKFoNBJ2Kx

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BIOGRAPHICAL SKETCH

Yuen Ting Yolanda Tsang was born in Hong Kong, China. After completing her high school in Hong Kong, Yuen entered the University of North Texas to pursuit a bachelor's degree in Geography in 2001. She received a Bachelor of Arts with a major in Geography from the University of North Texas in 2004. From year 2005 to 2008, she entered the master's program of Applied Geography with a concentration in Geographic Information System while obtaining a minor in Public Administration at the University of North Texas. She was the teaching assistant of geography and geology labs during her graduate studies. She was employed by Richland College as geography instructor after graduating from the University of North Texas in 2008. She entered the Geospatial Information Sciences doctoral program at The University of Texas at Dallas in 2009. Yuen worked at Tarrant County College and Tarleton State University as a Geography and GIS instructor between years 2014 to 2018.

CURRICULUM VITAE

TSANG, YUEN TING (YOLANDA) **Email: ytt090020@utdallas.edu**

Area of Expertise

- World geography, physical geography and human-environment interaction, Geographic Information Systems(GIS), emergency management, natural hazards(seismic), GIS and terrorism, medical geography, urban geography, internet mapping, remote sensing , 3-D GIS, physical geology.

Education

- **Doctor of Philosophy in Geospatial Information Sciences** 8/2009 – Present

  University of Texas at Dallas, Richardson, Texas *(Expected graduation May 2019)*

  Dissertation Topic: Building Recognizability in Urban Environments

  Final Oral examination passed on 12/20/2018

- **Master of Science in Applied Geography** 8/2005 – 8/2008

  Minor in Public Administration

  University of North Texas, Denton, Texas

  Thesis: "GIS Application in Emergency Management of Terrorism Events on the University of North Texas Campus"

- **Bachelor of Arts in Geography** 8/2001 – 12/2004

  University of North Texas, Denton, Texas

Professional Experiences

- **Visiting Instructor –Geography/ Geographic Information Systems (GIS)** 8/2018 – present

  Tarleton State University, Texas

  ▫ Taught college- level World Regional Geography classes to about 50 college students in lecture

  ▫ Taught college- level Human Geography class to about 30 college students

  ▫ Taught college-level Introduction to Geographic Information Systems course to about 30 college students in lecture and lab sections

  ▫ Developed interactive teaching material including both online and in-class activities

  ▫ Conducted and organized lab sessions to supplement lecture material

  ▫ Taught students about the latest Geospatial Technologies

  ▫ Created and customized lab exercises to provide adequate hands-on training to students

  ▫ Organizer of GIS Day – promote geospatial technologies and Geography/GIS program to both Tarleton and Stephenville community

- **Adjunct Faculty – Introduction to Geographic Information Systems class** 1/2018 – 5/2018

  Tarleton State University, Texas

  ▫ Taught college-level Introduction to Geographic Information Systems course to about 30 college students in lecture and lab sections
  ▫ Developed interactive teaching material including both online and in-class activities
  ▫ Conducted and organized lab sessions to supplement lecture material
  ▫ Created and customized lab exercises to provide adequate hands-on training to students

- **Adjunct Faculty – World Regional Geography and Physical Geography class** 4/2014 – 12/2017

  Northeast Campus, Tarrant County College, Texas

  ▫ Taught college-level physical geography and world geography material to 40 college students in each of three lecture sections
  ▫ Developed interactive teaching material including both online and in-class activities
  ▫ Conducted and organized various field works to supplement lecture material

- **Research Assistant –School of Management** 8/2010 – 12/2013

  University of Texas at Dallas, Texas

  ▫ Assisted department chair and faculty to conduct researches and analyzing data into the areas of global strategic management
  ▫ Applied knowledge of geography, geology, and GIS to conduct literature researches and preliminary data analysis for textbook publishing

- **Adjunct Faculty – World Geography class** 11/2008 – 5/2009

  Richland College, Dallas County Community College, Texas

  ▫ Taught college-level world geography material to 40 college students in each lecture
  ▫ Developed teaching material including lecture notes, PowerPoint presentation, exams, and in-class activities

- **Teaching Assistant – Earth Science and Physical Geology classes** 8/2005 – 8/2008

  Department of Geography, University of North Texas

  ▫ Taught earth science and physical geology material to 25 college students in each lab section
  ▫ Conducted 4 laboratory sections that supplemented faculty lectures
  ▫ Developed lesson plans and interactive lab exercises; taught application of thematic mapping, spatial and geological analysis in the field of earth science and physical geology
  ▫ Conducted field trips to illustrate local geological features in Denton

- **Lab Instructor – Advanced Statistics class** 8/2005 – 12/2005

  Department of Geography, University of North Texas

  ▫ Introduced both basic and advanced computer skills as well as geospatial techniques to students of statistics class; taught the application of SPSS and ArcGIS packages

- **GIS Analyst Intern** 6/2002 – 8/2002

  Environmental Protection Agency, Air Pollution Group; Hong Kong Government, China

▫ Prepared geospatial inputs and designed interface for air pollution dispersion model of East Asia
▫ Developed GIS data conversion program and verification of emission data

Professional Training and Certifications

▫ Remote Pilot Certificate (small Unmanned Aircraft Systems) **--** training in progress 04/2018
▫ FEMA Emergency Management Institute training course: IS-103--Geospatial Information Systems Specialist 5/2015
▫ Geospatial Intelligence Certificate, USGIF and University of Texas at Dallas 8/2013
▫ Remote Sensing Certificate, University of Texas at Dallas 8/2012
▫ GIS Certificate, ESRI, University of North Texas 8/2008
▫ ESRI Training Certificate, ESRI ArcIMS and Geodatabase Training Courses 12/2006

Membership and Awards

▫ Member of Association of American Geographers
▫ Member of the Geological Society of America
▫ Member of the Texas Community College Teachers Association
▫ Member of Alpha Lambda Delta National Honor Society
▫ Member of the National Association of Professional Women
▫ Member of Denton Chinese Church
▫ Presenter, Association of American Geographers Annual Conference 2008, Boston, MA
▫ President List - University of North Texas (12/2002)
▫ Volunteer and helper – GIS Day, University of Texas at Dallas
▫ Organizer and helper – GIS Day 2018, Tarleton State University

Professional Development and Research Projects

2014 Research Project **:** GPS and GIS application in tree management of Tarrant County College Northeast Campus, cooperation with Natural Science Department and Facilities Department

2010-2013 Research Assistant, Book "Strategic Management: Creating Competitive Advantages" by Gregory Dess, Alan Eisner, G.T. (Tom) Lumpkin , Gerry McNamara, 5th and 6th Editions, McGraw-Hill/Irwin

2012 DFW Metroplex Field Trip Leader, "DFW Metroplex Field Trip Guide 2012" , Geoscience Department, University of Texas at Dallas

2012 "Mineral Detection in Clay County, Texas: Remote Sensing Approach" Course Project, GEOS 5301, University of Texas at Dallas

2011 "GIS Implementation Plan: Richland College" GIS Implementation Course Project, University of Texas at Dallas
"Damage Assessment of Japan Tsunami 2011: Remote Sensing Approach" Course Project, GISC 7365, University of Texas at Dallas

2008 Application Developer, "GIS Application in Emergency Management of Terrorism Events on the University of North Texas Campus" , Research Project with Facilities Department and Geography Department, University of North Texas

2005 Research Team Member "Master Plan proposal, City of Roanoke, Texas" Proposed the master plan to City Council in December, 2005

2002 GIS Analyst Intern, data preparation for the publication "Air Quality in Hong Kong 2002" and " Hong Kong Air Pollutant Emission Inventory", Environmental Protection Agency, Hong Kong
http://www.aqhi.gov.hk/api_history/english/report/files/aqr02e.pdf

Courses Taught

▫ GEOS 5301 Geology of the Metroplex (Field trip leader)
▫ GEOG 4120 Medical Geography (Teaching assistant)
▫ GEOG 3190 Quantitative Method of Geography (Teaching assistant)
▫ GEOG/WSES/ENVS 2451 Introduction to Geographic Information Systems – lecture and lab (Adjunct faculty, Visiting Instructor)
▫ GEOL 1610 Physical Geology (Teaching Assistant)
▫ GEOG 1710 Earth Science (Teaching Assistant)
▫ GEOG 1303 World Regional Geography (Adjunct faculty, Visiting Instructor)
▫ GEOG 1301 Physical Geography (Adjunct faculty)
▫ GEOG 1320 Human Geography (Visiting Instructor)

Computer Skills

▫ Experience with ArcGIS 10.X and above, ArcGIS Pro, ArcGIS Online, MapInfo, QGIS, ERDAS Imagine, ENVI, Google Earth, Google SketchUp, CartoDB
▫ Landsat Data, GMT, GlobalMapper, Leica Geosystem, Zonal Geometry and Spatial Interpolation, Network Analyst, Spatial Analyst, 3D Analyst, Topology and Geometrical Operators, Server GIS, Geodatabase, Model builders
▫Programming - Visual Basic, Customization of ArcGIS, Python, SQL, HTML
▫Others – Microsoft Office Suite, Photoshop, Flash MX, Dreamweaver, SPSS, R , iOS Operations