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Do You See What I See? Assessing the Relationships between Demographics, Street Trees and Visual Recognition of Urban Buildings

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ABSTRACT: As more "green" cities are emerging in the 21st century, 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 public. 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 be able to retain much visual and spatial memories about a building or even a city because their views are obstructed. This paper begins with a thorough review of current and past literature about the relationship between buildings, street trees, and visibility in urban environments. The purpose of this research is to identify factors that influence visual recognizability of buildings in an urban environment such as distance away from buildings, presence of vegetation, frequent downtown visits, and physical forms of buildings using a geographic approach. 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 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.

KEY WORDS: Environmental Perception, Human-environment geography, Urban Planning, Urban Geography, Urban Design, Human perception, Urban Buildings, Urban Morphology

Introduction

Visibility and viewshed analyses have been applied to many disciplines 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 several 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 most 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 wayfinding, similar to visibility (Lynch, 1960).

Lynch asserts the strategic link in the process of wayfinding 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 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 1960s, 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 paper 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. 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?
4. What are the implications of investigating factors of the recognizability of buildings in an urban environment?

This study attempts to predict the potential attributes that influence the recognizability of buildings in New York City. This research is conducted to better understand how distance, socio-demographic factors, and vegetation influence the recognizability of buildings within the study area. 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.

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.

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 streetlights, 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?

Isovist and visibility

To further understand the theme of recognizability of this research, one must 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.

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 1). 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.

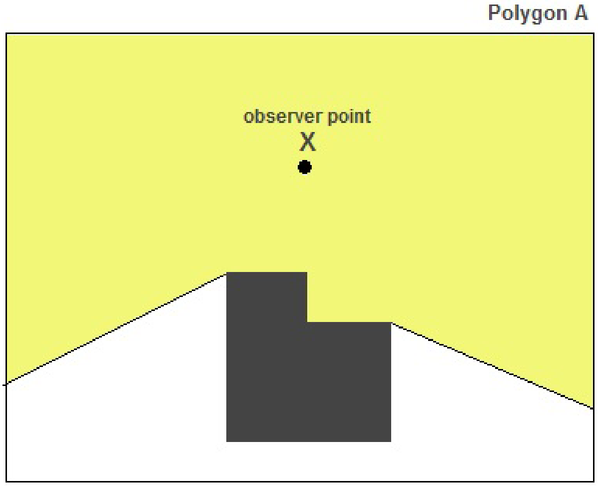

Figure 1. Illustration of isovist

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 (D TM) 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).

Visibility of 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 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 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 (a2 and a3) are not considered for calculation in the visibility analysis.

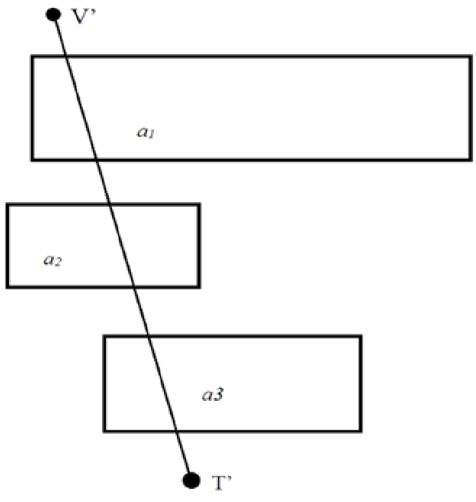

Figure 2. Projected LOS from V' to T' and building profiles

Yin et al. (2012) also used the parallel project ion approach to find the building polygon s that block ed 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 is 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 plane s 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 can 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 roof line 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.

Visibility and 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 paper, 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, thus, reducing the recognizability of that structure to inhabitants.

The concept of "Recognizability"

In simple terms, an innovative concept of "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.

The distance between an observer and the target objects (buildings) serves as an essential variable in visibility analysis (Pearson et al., 2014). 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 3 further explains the relationship between visibility and recognizability. The building in the center of the Figure 3 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.

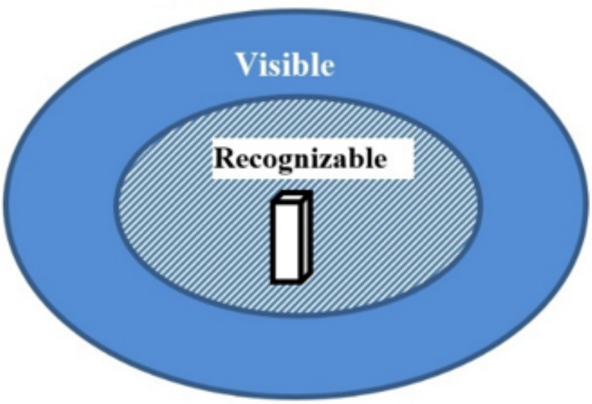

Figure 3. The spatial relationship between "visibility" and "recognizability"

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 4 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 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.

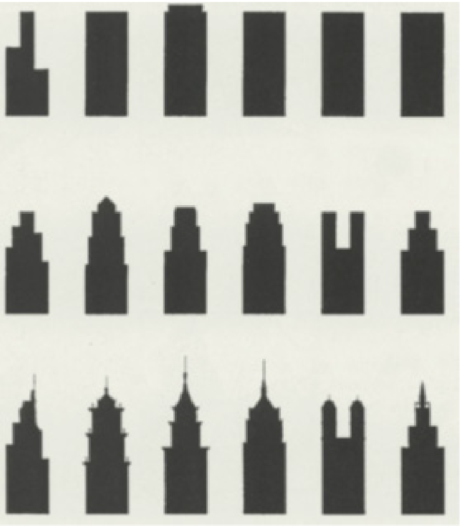

Figure 4. Different building profiles proposed by Heath et al. (2000)

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. 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).

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 4, some buildings have different towers that are not linked through a shared ground base (figure 5). 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.

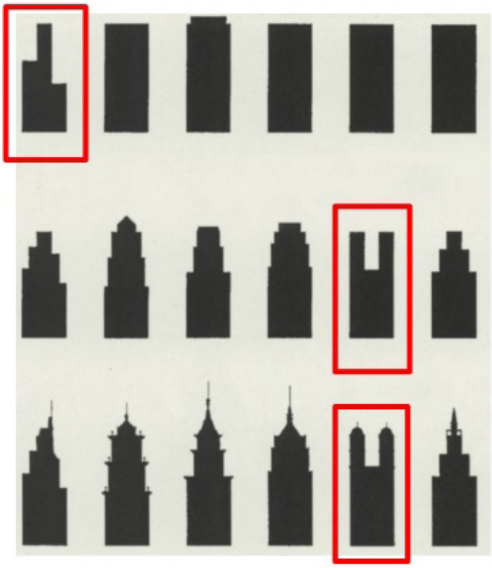

Figure 5. Buildings with towers and shared ground base

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 al., 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 socio-demographic 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 socio-demographic 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 socio-demographic 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 paper, 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 6 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.

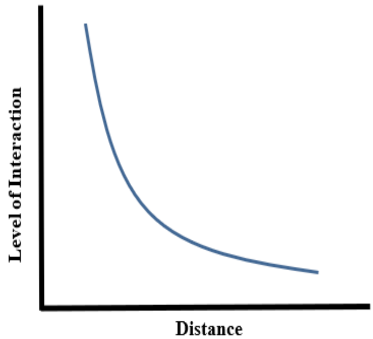

Figure 6. The distance decay model

Appleyard (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 traveling 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, Appleyard 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.

Methodology

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 paper 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 paper. In this paper, 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 of the high pedestrian volume locations according to the bi-annual pedestrian traffic counts report from the New York City Department of Transportation (figure 8). 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 wayfinding or navigation (Lynch 1969).

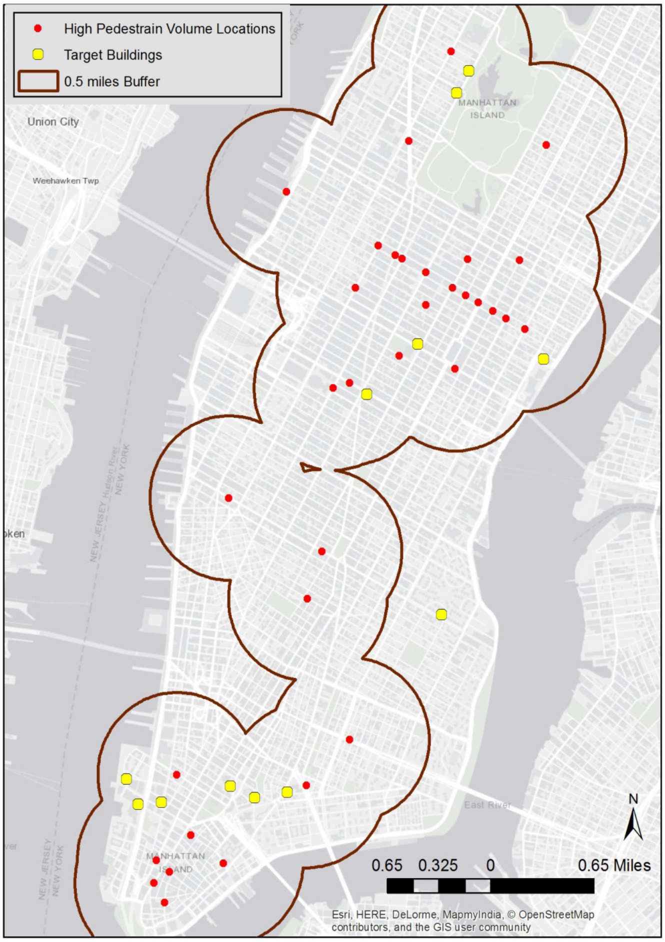

Figure 7. Locations of high pedestrians' volume and 12 target buildings

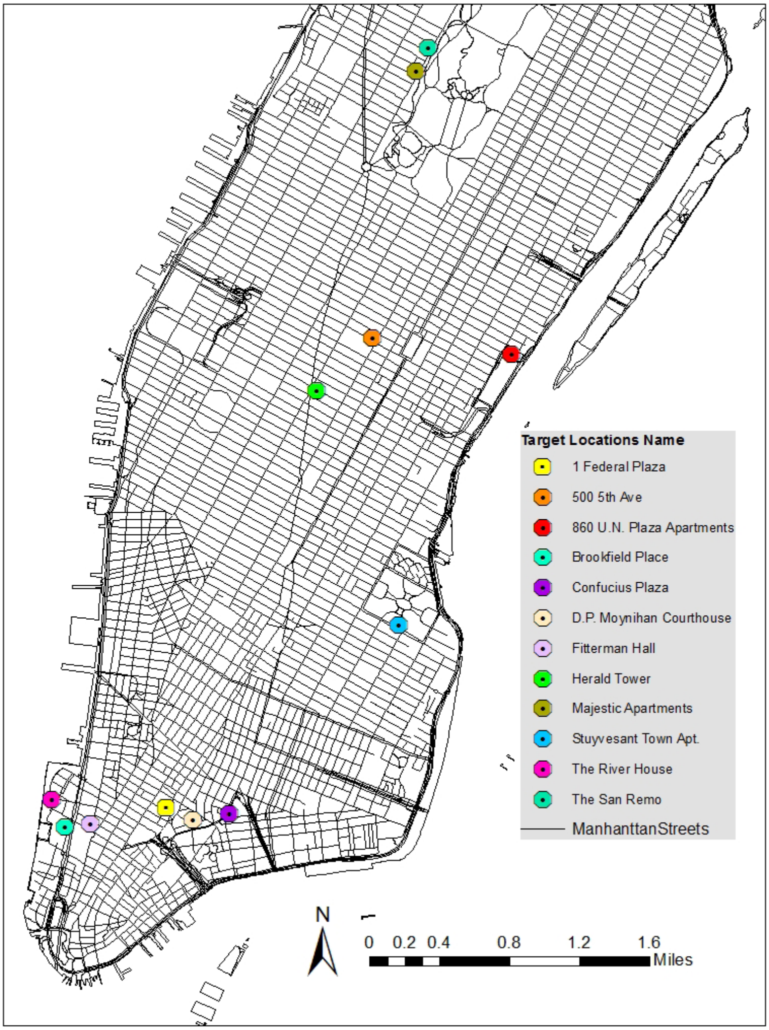

Figure 8. 12 Locations of target buildings

The 12 buildings are in fact of different usages of commercial, residential, and governmental activities (figure 8). All 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 1 and 2 lists the distances between the buildings when the photos are taken. The distance is measured using the measurement tool in Google Earth.

Table 1. Building Information

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

Table 2. Viewing Distance from 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

Results and discussions

It is important to further investigate how humans recognize the buildings from real photos to better understand how recognizability of buildings are attributed. A quantitative survey can be developed to gather responses 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.

We may assume the building with dense surrounding vegetation yield less correct responses because street vegetation covers significant amount of building façade. Factors such as age, sex, gender, ethnicity, education, residency, frequency of downtown visits, and previous New York City visits may also influence the rate of correct responses or the recognizability of buildings. We can also apply regression analysis to predict the factors that yield correct responses on the survey.

This research does not aim to provide an exhaustive description of the survey and advanced regression model; instead, presenting a preliminary method from a spatial perspective to investigate visual recognition or recognizability of urban buildings.

From the literature review in the previous section, 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. Demographic factors may also influence the recognizability of buildings and the result can be validated by a quantitative survey and future researches.

Conclusions

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 public. The complexity of building structure captures inhabitant's 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 be 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 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.

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 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.

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