Developing a Quantitative Method for the Measurement of Public Life-Supportive Urban Form:
Eight Test Sites and Applications in Seattle, WA and Copenhagen, Denmark

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Abstract

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Urban design theorists have developed a body of knowledge about the characteristics of places that support public life. More recently, researchers have developed quantitative methods for measuring certain aspects of urban form. However, little work has been done to apply quantitative methods to urban design theory. This thesis proposes a new metrics for representing urban form attributes of urban areas that support public life. These are organized as the Lively Urban Form (LUF) framework. The attributes measured were identified based on a review of influential urban design theorists dealing with urban form. The analytic framework was applied to eight study sites in Copenhagen and Seattle in order to test its ability to express urban form differences among these sites which affect their support for public life. Discussion of results, limitations, and potential applications of the method follow.

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1 Introduction

In 2017 an all-time high of 10,000 housing units are expected to be constructed in Seattle, capping off several years of explosive housing growth in the city (Rosenberg 2016). While the increase in demand driving this boom is evidence of the renewed attractiveness of urban living, the boom itself is remaking the form of the city. Despite the long-term consequences of design decisions in new construction, planners, developers, and citizens tasked with making decisions concerning urban design lack the necessary tools to concretely describe desired characteristics of urban form. Most often, plans rely on vague language and abstract, blunt measures like floor-area-ratio, dwelling unit density, retail square footage and lot coverage to indicate the types of development allowed or desired. These measurements can obscure as much as they illuminate about the qualities of urban form that affect the character of neighborhoods.

This thesis aims to describe qualities of urban form from a new direction: with quantitative measures of how the spatial characteristics of buildings and open spaces shape the public realm. These metrics convey how the size, shape, arrangement, and exteriors of buildings create environments which can be alternately lively, cluttered and complex, or tranquil, clean, and uniform. They provide a yardstick which may be used by professionals or citizens to communicate with greater clarity about the spatial characteristics of neighborhoods.

Generations of human experiment in the creation of urban environments have been helpfully preserved in the physical form of cities old and new throughout the world. Many of these places have been analyzed by researchers and theorists of urban design in order to discover both the qualities that make them unique, and how these qualities support human life taking place within them. The findings of these decades of work provide the basis for the development of the metrics in this study. Together these metrics comprise a framework for characterizing **lively urban form**. The framework is applied to eight study sites, four each in Seattle, WA and Copenhagen, Denmark in order to explore its effectiveness in illuminating the degree to which the built form of each site supports or fails to support public life.

These results are presented with along with contextual information about the sites, and are followed by a discussion of the clarity of the results of the study, reflections on the methodology used and a perspective on the potential utility of the Lively Urban Form (LUF) framework going forward. Two examples of how the framework could be used in professional research settings are also explored to better understand the method's strength and limitations.

2 Literature Review

This study beings with an analysis with the findings of urban design researchers and theorists about the form of urban environments that support public life. Since its formal foundation sixty years ago[1] the discipline of urban design has been chiefly concerned with a response to the Modernist approach to city building. Modernism held up the idea of a city composed of buildings that were free-standing, internally-focused, unadorned, aesthetically-unified, efficient solutions to the needs of humans for shelter and privacy. These buildings were big, as made possible by new construction methods. They were constructed and designed as singular objects, meaning that they did not combine with nearby buildings or open space to create a coherent form. The only coherent form was the building itself. The new role played by the building in the city caused a fundamental reordering of the shape of cities. And, in this instance, function followed form (A. Jacobs and Appleyard 1987).

The new shape of the city altered how people moved about, what kind of places they spent time in and how they interacted socially. Specialization of building and district functions helped eliminated unplanned interactions and chance encounters. The rationalist impulse to maximize the size of open spaces, buildings, and retail spaces lead to the creation of vast, monotonous environments. Prioritization of the automobile inherently penalized the pedestrian. All these forces lead to a radical reduction in the intensity and prevalence of life in public spaces (Carmona 2003).

For most of human history cities were formed of a dense built mass, cut through with narrow alleys, squares, and a few broader thoroughfares. These openings in the built form provided a space for the public life of the city in addition to circulation and access to buildings. The public

[1] At the first Harvard Urban Design Conference in 1956

realm was shaped by the many buildings which surrounded it and animated by the life that flowed through it into and out of these buildings. It comprised nothing more than the sum of the relationships between these elements (Kostof 1991).

The modernist approach to architecture and city building was an acknowledgment of the 20th century changes in construction and transportation technology and it was an earnest attempt to deal with the many problems of the industrial city, with its crowded, polluted, and unhealthy slums, economic inequality, and congested streets. Still, urban designers in the latter half of the 20th century found it necessary to repudiate many of the tenets of the modern city and its effects in their own work. This was perhaps most powerfully achieved by Jane Jacobs in her book *The Death and Life of Great American Cities*, in which she the compares modernist city planning to the archaic medical practice of bloodletting, saying "years of learning and a plethora of subtle and complicated dogma have arisen on a foundation of nonsense" (1961, 18). Jacobs calls out for a new discipline of city planning based on how cities work in real life, derived simply from the observation of cities themselves.

The key element that Jacobs searches for in her study of the real functioning city is **life**, and the circumstances and environments which sustain it in an urban environment. This life is found in the street, in Jacobs' "sidewalk ballet", in well-used parks and in safe, supportive, diverse neighborhoods (J. Jacobs 1961 pp 65-71). It exists in the public realm, a result of the complex interplay of the built elements of the city and of lives of the people who inhabited them. It is an elusive quality that is related to number of people in a place, the level of socializing taking place and the density of the network of interpersonal relationships they share. It can be approached indirectly with counts of people walking or sitting, measures of economic activity, participation in neighborhood groups or crime statistics. Beyond quantitative measures, Allan Jacobs attests there is a kind of “magic” which animates lively public spaces (1993, p. 271), while planning documents frequently envision something called a “vibrant” neighborhood. Jan Gehl, trained as an architect, perhaps best put it with the title of his first book, called simply “life between buildings” (1987).

2.1 Lively Urban Form

2.1.1 Many Buildings

If the public realm is shaped by buildings, it is vital to understand how the characteristics of these buildings impact the space around them. A chief complaint leveled by Donald Appleyard and Allan Jacobs in their work *Toward a Manifesto of Urban Design* is leveled against “gigantism” in the built environment: “[t]he elements of the city grow inexorably in size… and vast districts and complexes are created that make people feel irrelevant” and that they lack control over the places in which they live (1987, 114). To combat this Appleyard and Jacobs call for urban areas composed of many small buildings in diverse shapes and sizes, individually developed and designed, that have distinct characters and support a variety of uses and lifestyles. These compact buildings are more likely to depend on the street for access because they have less space for internal circulation, bringing their diverse and varied life into the public realm (A. Jacobs and Appleyard 1987).

The effect of small buildings on the public realm is further elaborated in the work of Jan Gehl through his dynamic concept of *assembly/dispersal*. In this dynamic, generators of activity may either be assembled into a coherent pattern around a lively public space or dispersed widely leaving public spaces dull and barren. Assembly requires a large number of buildings to arrange activity consistently around the public realm. It is an additive effect, meaning that each additional piece increases the vitality of the whole. By contrast, dead zones are created in spaces between large, centralized generators of activity in those environments where they dominate (Gehl 1987, 83–102).

While the spatial organization of buildings affects how they generate activity in public spaces, the size and number of buildings also contribute to the how an area is perceived by those passing through it. Physical environments composed of many and varied buildings engage and entertain the senses by increasing visual complexity (Gehl and Svarre 2013; Rapoport 1990). According to Gehl, humans desire visual stimuli about 1000 times per hour (once every four seconds) or at walking speed (about 3km/h) once every 3.3 meters. This level of interest has the "psychological effect of making the walking distance seem shorter" by dividing the trip naturally into manageable stages. When people enjoy passing through an area they are more likely to do it repeatedly, bringing life into the public realm (Gehl and Svarre 2013).

2.1.2 Small Public Spaces

Gehl's assembly of activity relies on the distribution of its generators around "a system of public spaces that is as compact as possible… so that distances for pedestrian traffic and sensory experiences are as short as possible" (Gehl 1987, 87). These compact spaces concentrate life. People tend to claim that they seek an "escape" or "sanctuary", but in William Whyte's meticulous observations of people spending time in public plazas he found the opposite to be true. According to Whyte "[w]hat attracts people most, it would appear is other people" (Whyte 1980, 19).

Writing in the late 19th century, Camilo Sitte also sung the praise for the physiological effect of compact plazas. He claimed the oversizing of new plazas in the industrial cities of 19th century Europe overpowered the surrounding buildings, having a "most pernicious influence" (Sitte 1889, 183). In these overly large squares the mutual relationship between the square and its surrounding buildings dissolves completely. Sitte notes that agoraphobia (the fear of open spaces) is a “new and modern ailment” which afflicts the former inhabitants of snug old towns who are used to cozy, small, old plazas when they are exposed to large, modern plazas (Sitte 1889, 183).

Human experience of size and distance are not arbitrarily defined, but rather are determined by the limited and specific powers of our senses. This aspect of how humans interact with their surroundings was first described by the anthropologist Edward Hall in his work *The Hidden Dimension* (1966). Human vision, for instance, struggles to identify anything but the most general information about an individual on the same horizontal plane at more than one hundred meters. At twenty meters’ distance, however, we begin to be able to decipher their mood and feelings, while at a distance of one to three meters, the space in which conversations usually take place, the detail and complexity information we receive is vastly increased. Meanwhile, the ability to perceive information about objects at the same distance but different vertical elevation is much reduced. As a result of our finite capabilities, open spaces that are overly large often feel cold and impersonal (Gehl 1987, 71; Gehl 2010).

The scale of open spaces also has dynamic relationship with the scale of buildings. This is noted by Jane Jacobs, who says “observers are forever rediscovering” the relationship between concentration and the city (J. Jacobs 1961, 261). According to Jacobs when open spaces are tight buildings can afford to be loose, with room for diversity in building types, ages, styles, and heights. Jacobs cites this quality in her beloved Greenwich Village, which she contrasts favorably with Stuyvesant Town. There, buildings are confined to one quarter of the land area, necessitating massive, standardized, efficient apartment buildings, leaving the remaining three quarters of the land vacant but untethered to any unique or interesting places (J. Jacobs 1961, 277–81).

2.1.3 Streetwall

The streetwall is the combined edge formed by buildings lined up against a street or square. It is a key feature of the traditional form of cities which gives definition and structure to the public realm of the street. An intact streetwall relies on buildings that work together to form a cohesive whole, in contrast to the modernist preference for isolated, singular works of art.

In *Toward an Urban Design Manifesto* Jacobs and Appleyard call for "buildings [that] should be arranged in such a way as to define and even enclose public space, rather than sit in space" (A. Jacobs and Appleyard 1987). This quality is called "positive space" by Christopher Alexander et al. in *A Pattern Language* (1977). A positive space has its own character as an "outdoor room" and is contrasted with "negative space" which is "shapeless, the residue left behind when buildings… are placed on land" (Alexander, Ishikawa, and Silverstein 1977, 518). Such negative spaces occur when long sightlines destroy the aesthetic unity of a space (Sitte 1889, 172). Alexander goes so far as to say "isolated buildings are symptoms of a disconnected sick society" (Alexander, Ishikawa, and Silverstein 1977, 532) because of the way they weaken people's sense of connection with their surroundings.

Intact streetwall also provides a structure that organizes the flow of activity within a public space. It both funnels activity into the public realm and directs flow within it. Gehl's concept of assembly of activity relies both on the presence of many activity generators *and* the organization of these pieces into a coherent, larger whole. Streetwall is thus an organizing principle which magnifies the ability of each individual piece of the built environment to the support public life of the whole (Gehl 1987, 87–89).

2.1.4 Orientation and Transparency

Beyond their shape, size, and arrangement, the orientation of buildings also impacts their relationship with public space. The quality of the façade, the placement of entrances, windows, and the floor plan of a building can either engage with the street or turn away from it. Street-oriented buildings were common, but not universal, in pre-modern cities. In certain times and places the private realm has been prioritized with buildings oriented inwards towards courtyards. Here, the only engagement with the street comes from the entrances. When this has occurred, streets functioned more as a corridor for travel and less as space for interaction and socializing (Kostof 1991, p. 198).

When cities have developed with a pattern of street-oriented buildings, the liveliness of the public spaces onto which they front is increased (Gehl 1987, 87). Building orientation plays an important role in another of Gehl's dynamic concepts about life between buildings, called *opening up/closing in*. Buildings that open up to the street allow passersby to interact with them in some way; they can perceive something about what is happening inside the building and may even be invited to join in. Likewise, people inside buildings that open up to the public realm are able to observe the life of the street or square, providing them with entertainment ("people watching" in the modern parlance) as well as offering "eyes on the street" for safety. Displays, marquees or merchandise on display can all build on this connection (Gehl 1987, 123–29).

The orientation described by Gehl has to do with the concept which is called *transparency* by some scholars. Transparency in this sense is related to the permeability of the boundary between the public realm and the private: that passersby can sense what is going on inside and that a there is communication between the life within the building and that without. Naturally, transparency includes the visual link provided by transparent ground-floor windows, but it also comes from sensory clues such as the smell of roasting coffee, the sound of live music, or signs and visual displays. According to Allan Jacobs it is one of the essential qualities of a “great street” which provides “an invitation to see or know, if only in the mind, what is behind the streetwall”. Elements such as windows, entrances, low fences or hedges and outdoor seating all increase the quality of transparency (A. Jacobs 1993, 285–87). Glimpses into industrial or construction sites can be particularly interesting for passersby as well, as they make the daily act of creation and re-creation of the city visible (Gehl 1987, 123).

Taken together, these observations of how urban form affects the liveliness of the public realm indicate several general characteristics that help foster a lively street environment. An abundance of buildings, retail businesses and other generators of activity create an environment that is **rich in places** to go and things to do and see. An environment with a relatively small amount of open space and defined edges in the form of continuous streetwall will have a sense of **enclosure**. Areas in which buildings are oriented towards the street with prioritized street-facing façades and an abundance of street-accessible entrances have greater transparency and **engage** with the public realm. This thesis develops quantitative measures for these three qualities of urban form that contribute to lively public spaces: **place-density**, **enclosure**, and **engagement**.

2.2 Quantifying Urban Design

The classic body of work by 20th century urban design scholars cited above is based on the work of group of authors over a thirty-year period. The theories of this school of thought based are upon the intense, loving observation of real cities suggested by Jane Jacobs, and how real people move about them, paired with detailed study of the places in these cities that seem to best serve the needs of their occupants (1961, 19). However, these authors arise from a limited set of backgrounds, with all being European or American whites, and with one exception all male.

In many cases influential theories of urban design are based on systematic observation and recordings of people walking, sitting and standing in public places which are used to theorize characteristics of urban design that encourage such behaviors (Whyte 1980; Gehl and Svarre 2013). However, there has been little empirical validation of this body of work (Ewing and Clemente 2013, 3). According to Cuthbert "most of urban design theory is self-referential and legitimated on the basis of personalities… and movements rather than any consistent integrity of its own, some of it bordering on mysticism" (2011, 86). This has led researchers in two directions: while Cuthbert attempted to develop a "theory *of* urban design" that ties the existing "theories *in* urban design" (2011, 86), other researchers have attempted to test the validity of existing theories through measurement and statistical tests.

The project of validating theories about urban design is challenging because urban design deals with "wicked problems". These are problems that are very complex, which arise from interrelationships of a wide array of often seemingly unrelated factors, and about which consensus agreement on the desired solution can be difficult to reach (Rittel and Webber 1973). As noted by Jane Jacobs, the easy, efficient solutions to the wicked problems of urban life pursued by well-intentioned modernist urban planners and architects often led to results that were unpopular and unsuccessful (J. Jacobs 1961).

Existing quantitative tools used by the urban planning discipline proved poor for understanding questions of urban design. This weakness was demonstrated by Peter Owens in 1993 who described two neighborhoods in Seattle - Wallingford and Lake Hills - which had similar characteristics according to standard planning measures such as dwelling unit densities, land use mixes, median rents and housing values and in demographics in terms of age, household size, land tenure, and socio-economic class. Yet, qualitatively the two neighborhoods had striking differences that “any third grader could tell us about,” with Wallingford an old, heterogeneous urban neighborhood characterized by bungalows and main-street retail and Lake Hills a homogenous, automobile-oriented suburb (Owens 1993, 143). Owens proposed how new measures related to distinct physical characteristics of the neighborhoods such as building/parcel/block size, building/street relationships, and building types could shed light on the important differences in form between these two neighborhoods. Owens further proposed that such measures could better explain the impact of neighborhood form on behavioral phenomena such as the level of walking behavior that occurs in each (Owens 1993).

In the ensuing decades researchers have explored these and other variables in order to develop a methodology of scientific analysis of urban form. The progress of one branch of this research has been greatly aided by the advancement of Geographic Information Systems (GIS) technology for systematically analyzing quantitative properties of geography. GIS researchers have developed statistical methods to compare urban form in different cities and neighborhoods that rely on factors such as the density of road intersections, the proximity of residences to commercial services, the presence of sidewalks, bikelanes, and multi-use paths, and land value in addition to classic measures such as land-use mix, dwelling unit density, and amounts of undeveloped land (Nedovic-Budic et al. 2016). The rise of the internet has made such quantitative tools for understanding urban areas accessible to the lay consumer as well, a phenomenon perhaps most clearly seen in the ubiquity in real estate marketing of Walkscore® brand quantitative assessments of transportation accessibility.

GIS-based research into urban form variables can be undertaken to assess qualities such as the degree of “sprawl” (Song and Knaap 2007) or to compare the correlation of urban form patterns with other patterns of human behavior. One fruitful area of GIS-based urban form research has been the investigation of associations between walking behavior and urban form to better understand the public health impacts of urban form design (Saelens et al. 2014). Walking, which is both of form of transportation and simply a state of human being, is a fairly convenient variable to stand in for the concept of public life. Moreover, walking behavior has public health implications, increasing the relevance of the research to a greater number of researchers and potential funding streams.

A recent effort in this vein was undertaken by a group of researchers in South Korea who in 2015 published a work entitled “Operationalizing Jane Jacobs’ Urban Design Theory”. In this work they developed a quantitative approach to measuring urban design using the four kinds of diversity necessary for lively cities identified out by Jacobs (Sung et al, 2014). The variables measured include elements of urban form such as intersection density and building density, but also included information about building uses and population density as well as the proximity to “border vacuums” such as parks and highways identified by Jacobs. These variables were processed using GIS and were correlated with information on walking behavior based on wearable GPS devices.

The enormous scope of data collection made possible by the development of GIS has given researchers a powerful tool for assessing the spatial properties of urban areas, however there are many characteristics of urban design that are difficult to measure using solely GIS. A different quantitative approach to assessing the work of classic urban design theorists has been undertaken by Reid Ewing and others in a series of works which led to the development of a framework for measuring urban design called the Maryland Inventory of Urban Design Qualities (MIUDQ). This framework uses street-level measurements to develop scores based on the qualities of imageability, enclosure, human scale, transparency and complexity; qualities described by urban design theorists as being necessary for lively, walkable streets. The framework records a broad range of factors, from the presence of distinctive signage to the number of passing cyclists to the visibility of the sky overhead. The measures have been designed to be simple enough that they can be recorded by an observer with minimal training (Ewing et al. 2006; Ewing and Handy 2009; Ewing and Clemente 2013; Ewing 2016).

The MIUDQ framework has been tested by researchers in New York City and Salt Lake City to explore relationships between urban design characteristics and walkability (R. Ewing and Clemente 2013) (Hassan Ameli et al. 2015). Nothing in the framework necessarily ties it to walkability, however. The MIUDQ framework could easily be used to attempt to explain other kinds of human behavior, potentially opening up new avenues of learning about how urban design affects the lived experience of place. More simply, the MIUDQ framework could be used by urban planners as a metric of urban design quality.

While the MIUDQ and the work of GIS-based researchers provides us information about street-level characteristics of urban design and general characteristics of urban form respectively, significant gaps exist in the tools available to measure urban design and urban form at other scales. As far as can be reasonably ascertained, no quantitative tools currently exist for expressing how urban form at the neighborhood scale aligns with the classic theories of the urban design cannon for the development of lively streets and public spaces.

3 Thesis Design

3.1 Summary

The aim of this project is to develop new quantitative measures of how buildings shape urban form at the multi-block scale. It measures several spatial qualities of buildings and open spaces to determine the degree to whether the physical form of the site is supportive of a lively public realm. As spatial attributes of physical objects, these can be measured and analyzed quantitatively.

The metrics developed for this study are based on qualities of urban form that have been indicated by urban design theorists over many years as being key to creating interesting, attractive, walkable, lively urban space. This urban form is characterized by narrow streets and small public squares lined with many buildings and enlivened by shops, doorways, and decorated façades. Three metrics are developed in this thesis that measure the degree to which these characteristics are present in study areas of equivalent size. The metrics are: **place-density**, **enclosure**, and **engagement**. Together they comprise a framework for measuring **Lively Urban Form** (LUF).

In this thesis eight study sites are assessed using the LUF framework, with four sites in Seattle and four in Copenhagen. The findings of this assessment and the degree to which the framework succeeds in illuminating differences and similarities between sites is then analyzed. Finally, reflections on the potential utility of such a framework for measuring urban form are offered.

3.2 Definition of Terms

Before describing measurement methods and construction of metrics, it is necessary to define the specific terminology used in conceptualizing and measuring urban form in the study's context.

3.2.1 Public Realm/Private Realm

The metrics developed in this thesis are chiefly concerned with the perception of urban form from the perspective of an observer passing through the public realm. The public realm has both physical and social dimensions, though only the former is assessed here. For Matthew Carmona *et al.* "[t]he *physical* public realm is understood here to mean the spaces and settings – publicly or privately owned – that support or facilitate public life and social interaction" (2003, 109). The physical public realm includes external public space (e.g. streets, parks, parking lots, etc.) internal public space (e.g. libraries, etc.), and quasi-public space (restaurants, shopping malls, university campuses). This thesis is particularly interested in the urban form qualities of the external public space, which according to Carmona consists of "pieces of land that lie between private landholdings" (2003, 111).

For this thesis, the public realm has been defined as the open space in a study site that can be reasonably assumed to be accessible to the public. On commercial and industrial sites, this includes all outdoor areas where customers or non-employees are permitted to be present, such as parking lots and building setbacks. Setbacks are often landscaped, but remain essentially open to public movement and occupation. Fenced areas that are clearly off-limits to the public are not included. All other areas, including buildings, are counted as part of the private realm.

On residential properties, open space that is on a parcel which is shared by no more than four dwelling units is considered part of the private realm. Open space shared by four or more units that requires passage through a gate or narrow opening is also considered private. Open space shared by more than four units with no separation from the street is considered part of the public realm. Parking lots used by buildings with more than four units are considered part of the public realm. All space in the public right-of-way is considered public realm as are all public parks and squares. The public right-of-way consists of land over which an easement for public travel exists and includes roadways, sidewalks, and planted areas.

This approach towards measuring the public realm assumes a single, continuous ground plane which is either open or occupied by buildings. In places where severe changes in topography or grade-separated privately-owned-public-spaces (POPS) are present, data collection about the size of the public and private realm will be more difficult and may become unfeasible.

3.2.2 Place

For the purposes of this project place has been operationalized in an extremely limited way to mean only buildings, businesses, and parks. This is based in part on Thomas Gieryn's definition, in which a place is described as having three necessary conditions: a place has a location, a physicality, and some meaning which can be expressed with a name (Gieryn 2000). Of course, places come in all sizes and they may nest within each other: Cities are places and neighborhoods are places, and rooms and specific items of furniture can also be places (Entrikin 1989). For the purposes of this project only places that are perceptible from the public realm are of interest. In this case, the address of a building serves as its name: a unique, if utilitarian, signifier for the physical entity in a specific location. Street-front retail businesses and similar uses which are sustained by visits from members of the public (churches, street-front offices, public outreach “storefronts”) also meet the definition for places, with set locations, physical spaces, and unique names.

The presence of housing or office uses within buildings is represented as a binary value per building (i.e,, either present or not present). While the general presence of these uses can usually be perceived, the unique identity of each office tenant or dwelling unit is not perceptible from the street, meaning they do not register to the outsider as individual places. Public parks are also counted as places, although there are none in any of the study areas assessed in this project.

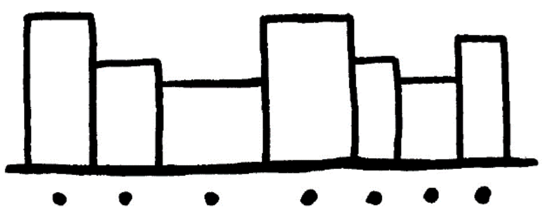

Figure 3-1. Count of buildings illustration.

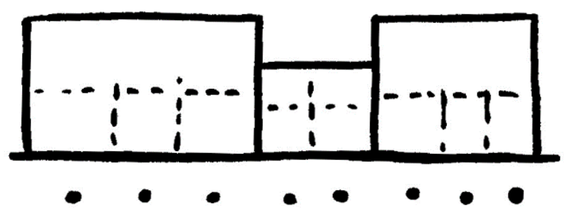

Figure 3-2. Count of retail spaces illustration.

3.2.3 Streetwall

Streetwall is the line of building façades that abut the right-of-way easement. A “perfect” streetwall lines the edge of the right-of-way without gaps from corner to corner. Buildings which do not directly abut the right-of-way also provide some sense of enclosure. To account for this, buildings that are less than one half of the width of the right-of-way distant from the right-of-way edge are also counted as part of the streetwall. The entire length of the block from right-of-way to right-of-way is counted as the potential streetwall and the existing length of streetwall is taken as a proportion of this potential. This measurement of streetwall relies on the assumption that study sites areas with buildings surrounded by public rights-of-way. In areas where this is not the case, the measurement of streetwall outlined here will not be feasible.

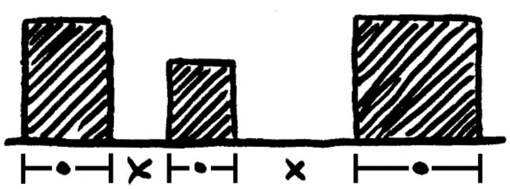

Figure 3-3. Streetwall illustration.

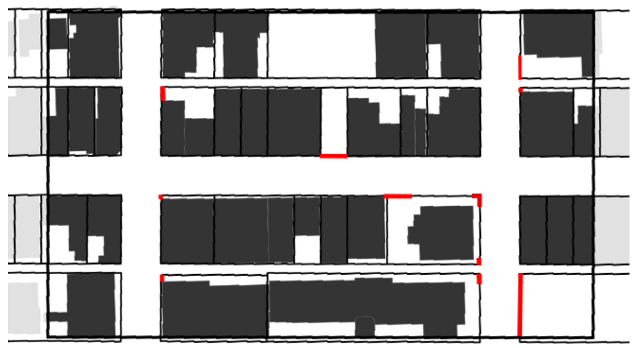

Figure 3-4. SEA 2 with streetwall gaps marked in red

3.2.4 Orientation

The simple definition of orientation is “to set or arrange in any determinate position”. For this study building orientation was measured as a binary variable. Recording orientation as a binary simplifies scoring, but leaves out potentially important gradations in the degree to which buildings are oriented towards the street.

A building being “street-oriented” is defined as having no more than two street-facing sides, and *either* having its most ornamented façade(s) on the side facing the street(s), *or* having entrances and windows primarily located on the building’s street-facing side(s).

A building’s side is street-facing when it is no more than one half the right-of-way width from the edge of the right-of-way.

Figure 3-5. Street-oriented building with ornamental façade.

Figure 3-6. Street-oriented building with street-side entrances.

Figure 3-7. Building oriented away from street.

Figure 3-8. Back side of street-oriented building

3.2.5 Entrance

Entrances to businesses have only been counted if they appear to be accessible - i.e. unlocked from either the inside or outside - during normal business hours. While it is not possible to verify if an entrance is unlocked based solely on photographs, the utility of an entrance depends on the potential user being able to assume that it is unlocked. This is primarily communicated to the public by architects and buildings managers based on placement and signage. Entrances to residential buildings are counted unless they appear to primarily provide access to utilities or maintenance facilities. Figure 3-9 shows an inaccessible entrance, Figure 3-10 shows an accessible entrance, and Figure 3-11 shows accessible residential entrances.

Figure 3-9. Mixed use building – no public access.

Figure 3-10. Business entrance.

Figure 3-11. Residential entrances.

Parking garage entrances were also counted. No urban design literature was found during the literature review which cited a positive role for parking garage entrances in creating a lively urban form. However, this type of building entrance does provide public access to the building, increasing its engagement. They are often used by people on foot in addition to people in cars.

3.3 Study Sites

Eight study sites were selected to test the Lively Urban Form (LUF) framework in this study. Four sites are located in Copenhagen and four in Seattle. Each site is 250 meters (820 feet) by 150 meters (492 feet) with a total area of 3.75 hectares (9.26 acres) and has its long axis centered on a prominent commercial street. The shape and size of the study area is designed to collect data about a multi-block area within an urban neighborhood which could be effectively surveyed in a manageable amount of time. The boundaries of the study areas are delineated to form a rectangle with one long axis so that the study site could be centered along a commercial street while including some portion of the cross streets on either side. This keeps all of the area within about one block of the main street. Future applications of the LUF framework may utilize sites of different size or shape.

Sites were chosen to span a range of different neighborhood characters and ages. Study sites were chosen in the cities of Seattle and Copenhagen for convenience (the researcher was living in these two cities during and immediately prior to developing the study). They are intended to embody the differences which would be instantly recognizable to the “five-year old” mentioned by Owens (1993, p. 143) while holding enough characteristics in common in use-mix and intensity to allow for relevant comparisons.

3.3.1 Copenhagen

The four sites in Copenhagen represent neighborhoods of different ages and are characterized by different building types. These sites were selected during the fall of 2016 during a research project on urban morphology. This research offered an excellent opportunity to identify sites which were characteristic of dense neighborhoods throughout the city. The four Copenhagen sites are labeled CPH 1 through 4.

Figure 3-12. Map of Copenhagen showing streets and study sites.

3.3.1.1 CPH 1 – Indre By

Figure 3-13. Strædet - the main street in CPH 1. Source: author.

Figure 3-14. CPH 1 building footprints.

CPH 1 is located in the oldest part of the Copenhagen, known as *Indre By* or “inner city” centered on the pedestrianized street Strædet. This area has been the center of the city since medieval times and generally the street network and property boundaries date from that era. The center point of the site is located 244 meters from the city center at Nytorv square. Over the years this part of the city was rebuilt several times after catastrophic events leveled the city, most recently after the Great Fire of 1785. As a result, most of the buildings date from around 1800, while the shape and sizes of lots, streets, and squares is much older.

This area of Copenhagen is renowned for its inviting and pleasing pedestrian environment, with “Stroget” located just north of the study area. Stroget was reclaimed as a pedestrian-only street in 1962, beginning a gradual transformation of inner Copenhagen into an environment in which pedestrians and cyclists have been increasingly prioritized and protected and motor vehicles have only a limited presence.

These blocks are characterized by buildings with apartments above ground-floor retail uses. Most buildings are around three or four stories, many with partially exposed cellar stories housing non-residential uses. The buildings have narrow frontages and fit together to form a continuous streetwall on nearly every block face. These buildings all have access to a courtyard which is usually shared with at least one other building. The inner space of these blocks are occupied by back buildings which are accessible from the courtyard and are usually share a parcel with a building fronting on the street.

3.3.1.2 CPH 2 – Vesterbro

Figure 3-15. Istedgade - the main street in CPH 2. Source: author.

Figure 3-16. CPH 2 building footprints

CHP 2 is located in *Vesterbro*, one of the *brokvarter* or neighborhoods which rapidly grew up around old Copenhagen in the late nineteenth century. The site is centered on Istedgade, formerly one of the streetcar lines around which this neighborhood was platted and built out from around

1860-1890. Most of the buildings date from this period. Blocks tend to be large with straight streets which run at irregular angles.

These blocks are characterized by five to six story walk-up apartment buildings, many of which have ground-level retail spaces. They are characterized by similar dimensions and architectural styles, and fit together to form a continuous, straight, relatively uniform streetwall along almost all block faces. These buildings enclose a single large courtyard on each block.

3.3.1.3 CPH 3 – Outer Nørrebro

Figure 3-17. Tagensvej – the main street in CPH 3. Source: Google.

Figure 3-18. CPH 3 building footprints

CPH 3 is located in outer *Nørrebro* about 3.26 kilometers from the city center and is centered around the arterial street Tagensvej. This area on the outer edge of Nørrebro, was not built up until that early twentieth century. Some of the buildings date from the turn of the century, a period in which the Danish government began to take measures to increase the funding available for the construction of housing. Consequently, these buildings tend to be larger than those in older sections of the *brokvarter*. This trend towards larger and more specialized buildings for housing continued when construction resumed after World War II. During these years government-funded social housing associations played an increasingly prominent role in housing creation, with a preference towards large footprint, functionalist building designs.

This neighborhood is characterized by walk-up apartment buildings five to six stories high with very long street frontages. Some building complexes enclose entire blocks. All buildings have access to a courtyard which is shared with the whole block but which may be subdivided with fences. Streets are straight and roughly follow an orthogonal grid. Buildings dating from before 1930 tend to have limited ornamentation which is oriented towards the street. Later buildings embrace a functionalist style and eschew ornamentation, with a neutral orientation, or an orientation towards the courtyard.

3.3.1.4 CPH 4 – Sluseholmen

Figure 3-19. Sluseholmen - a cross street in CPH 4. Source: author.

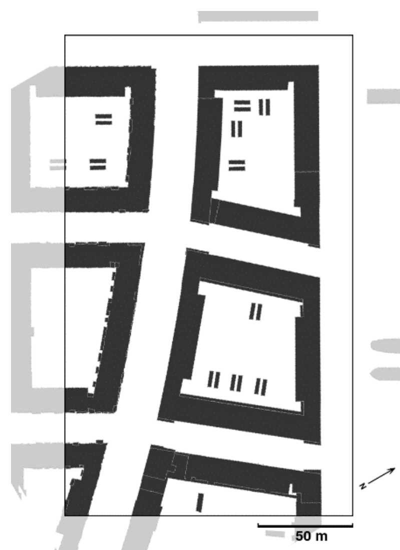

Figure 3-20. CHP 4 building footprints.

CPH 4 is located in the *Sluseholmen* neighborhood in Copenhagen's *Sydhavn* or “South Harbor”, a formerly industrial area in the process of being redeveloped with residences and offices. The *Sluseholmen* neighborhood was constructed as a single public/private-development project in

2009. The site is on an artificial island in the harbor and is cut through with a grid of canals complementing the street-grid.

Each block is composed of a single building four to seven stories tall that encloses a courtyard. Each building has multiple entrances from the street and several include ground-floor retail spaces. The courtyards are accessible to the public through cut-through openings in the bottom two stories of the streetwall.

3.3.2 Seattle

The four sites in Seattle were selected by the researcher with the goal of representing the range of mixed-use dense neighborhoods in the city. The selection was based on the knowledge gained from many years spent living in the city. The four Seattle sites are labeled SEA 1 through 4.

Figure 3-21. Map of Seattle showing streets and study site locations.

3.3.2.1 SEA 1 – Capitol Hill

Figure 3-22. Pike St - the main street in SEA 1 on a snowy day. Source: author.

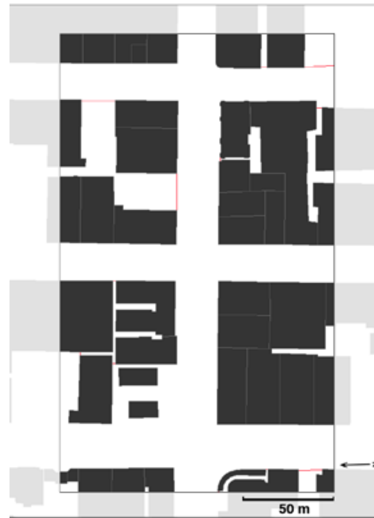

Figure 3-23. SEA 1 building footprints.

SEA 1 is located in the Capitol Hill neighborhood, centered around Pike Street on the busy Pike/Pine corridor. This site is located approximately 1.5 kilometers from the center of Seattle's downtown (defined as 3rd and Union for this project) and is characterized by a mix of historic residential, commercial, and light industrial buildings which have been repurposed and modified for mostly residential and retail uses. It has a street grid typical of Seattle with blocks 300 feet (91.4 meters) by 400 feet (121.4 meters) without alleys. The district has perhaps the busiest nightlife in the city, with numerous restaurants and bars.

The buildings here range from one to six stories in height and have a wide range of footprint sizes. Most front onto the street with no setback and receive light from the street fronting side and a rear lot. The buildings are tightly packed with high land coverage and no courtyards, however some have parking lots or narrow outdoor spaces.

3.3.2.2 SEA 2 – University District

Figure 3-24. University Way "The Ave" - the main street in SEA 2. Source: author.

Figure 3-25. SEA 2 building footprints.

The second site in Seattle is located on University Way, locally known as “The Ave”, in the University District about 5.5 kilometers from downtown. This district was built around Seattle’s streetcar network, operational from the late nineteenth century until the 1940’s. The neighborhood consists of a grid of blocks 640 feet (195 meters) by 250 feet (76.2 meters) with alleys. It is characterized by one and two-story retail buildings mixed in with three to eight story apartment buildings, many of which include ground-level retail spaces. Churches and office buildings are present as well.

3.3.2.3 SEA 3 – South Lake Union

Figure 3-26. Denny Way - the main street in SEA 3. Source: author.

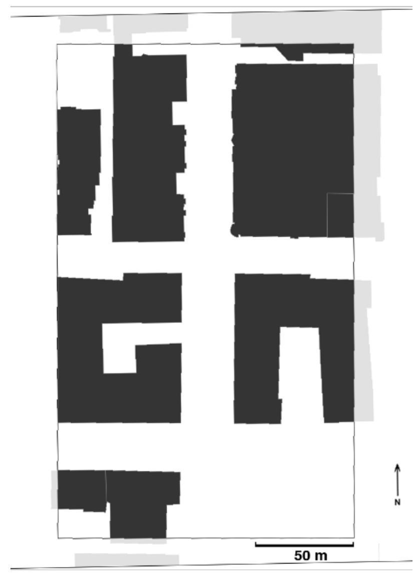

Figure 3-27. SEA 3 building footprints.

SEA 3 is located on the western edge of the South Lake Union district about two kilometers from the city center. This formerly low-intensity industrial and mixed-use district area has been heavily redeveloped in the past decade with high-density offices and residences. It generally maintains the typical Seattle street grid with blocks 300 feet (91.4 meters) by 300 feet and no alleys, however topography and infrastructure interrupt this grid in places.

Many of the existing buildings were constructed since 2000 and tend to be large, some occupying entire blocks. They are mostly 5-7 stories tall. In the study site most are apartments, with some retail spaces on the ground floor.

3.3.2.4 SEA 4 – Northgate

Figure 3-28. Northgate Way - the main street in SEA 4. Source: author.

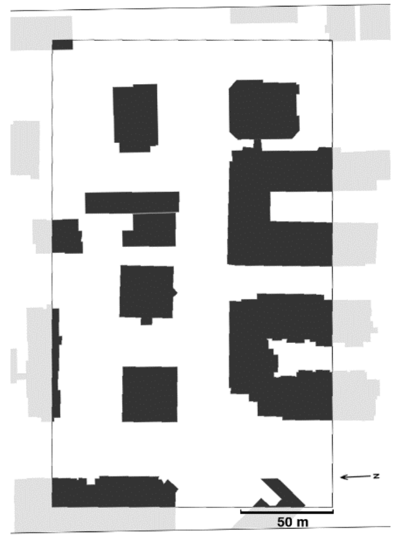

Figure 3-29. SEA 4 building footprints.

SEA 4 is located just northeast of the Northgate Mall in the eponymous neighborhood in the north part of Seattle, approximately 11.3 kilometers from the city center. It transitioned from agricultural and low-density residential land uses to more intense automobile oriented commercial use in the post-World War II years with both the nearby mall and Interstate 5 opening around 1960. More recently residential construction has taken place, with large apartment complexes constructed throughout the commercial center. The site is nominally part of the Seattle street grid, however only major arterials have been built while other rights-of-way have been vacated. This site contains both one-story retail buildings and five to seven story residential buildings. It also contains a seven-story parking garage/retail building. There are large spaces occupied by parking lots.

3.4 Data Sources

3.4.1 Site Visits

Prior to determining final study locations study sites were visited in both cities, during which basic impressions and information were recorded. Site visits in Seattle took place between January and April, 2017. Copenhagen site visits took place between September and December, 2016. Once sites were selected, further site visits allowed the researcher to verify new construction and other recent changes in the built environment of each site.

3.4.2 Google Maps

Much of the data for this project was collected remotely using Google Maps (Google, Mountain View, CA). The satellite images, "3-D View", and "Streetview" functions of this web tool allowed data collection of nearly all of the measurements. Streetview was used to conduct the retail space and entrance counts, to record residential and office uses, and to determine the orientation of buildings. Streetview also proved useful in identifying edges like fences and grade changes that prevented public access into private realm open spaces.

3.4.3 GIS Data

Shapefiles of building footprints and parcels were downloaded from the City of Seattle and Copenhagen Municipality. Building ages for the Seattle sites were downloaded from the King County Tax Assessor's Office web site and merged with parcel data in ArcGIS.

3.4.4 Other Sources

Building-specific data for Copenhagen study sites was obtained from Offentlige Informationsserver, a publicly available database of information relating to properties in Denmark found at https://www.ois.dk/. Building-specific data for sites in Seattle was obtained from the King County Tax Assessor. "Walkscores" for study sites was obtained from www.walkscore.com.

3.5 Data Analysis

3.5.1 ArcGIS

Spatial information about buildings and open spaces was managed using the geographic information systems (GIS) software ArcGIS Desktop version 10.3.1 (Esri, Redlands, CA). Within ArcMap, the building footprints were modified based on the most recently available aerial photography to reflect changes since the files were created. Some errors in the shapefiles was also corrected. ArcMap was used to conduct building counts, measures the size of the public realm, and streetwall gaps. JPEG images were created from ArcMap and imported into Photoshop for further manipulation and analysis.

3.5.2 Adobe Photoshop

Images produced in ArcMap of each study site were imported into Photoshop (Adobe, San Jose, CA) to measure the area of the public and private realm. In order to find the area of the site located in the public realm, the magic wand tool was used to select all contiguous pixels colored to mark open space. This pixel count was compared to the pixel count of the study site overall. This method for determining public realm size was quick and easy but potentially not as reliable as an ArcGIS-based approach to collecting this data, due to the way Photoshop sometimes compresses pixels in large images. In future applications of the LUF framework it is recommended to use ArcGIS or another geographic analysis tool to make this calculation. Photoshop was also used to create diagrams to display data collected.

3.6 Metrics

Each of the LUF metrics convey the degree to which urban form qualities that support liveliness are present at a site. These metrics are **place density**, **enclosure**, and **engagement**. The metrics each consist of several individual measures and are constructed with the goal of balancing simplicity of data collection against the comprehensiveness of each measure. The three metrics are combined with equal weighting to produce an aggregate Lively Urban Form score.

3.6.1 Place Density

Buildings, shops, parks and squares all help make an area more interesting and lively. The place density metric describes the number of such places in defined area.

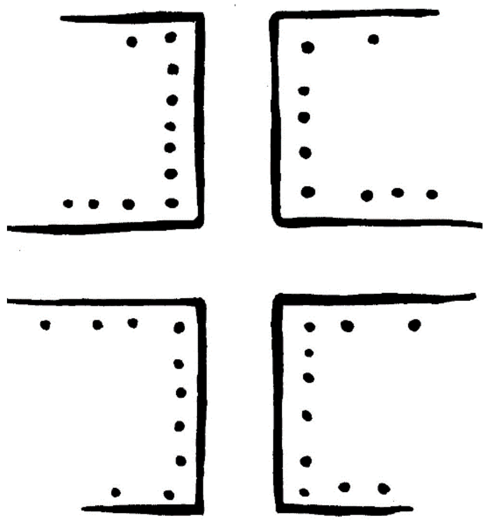

Figure 3-30. Place density conceptual diagram.

Buildings, retail spaces, parks, and the presence of residential or office uses within a building are counted as places. Although each of the study sites in this thesis measured 3.75 hectares, the density of places per hectare (10,000 m^2) was calculated to provide a consistent basis for comparing sites of different sizes in the future. Place density is calculated as shown in Equation (3.1).

$$PD = \frac{(B + R + RES + OF)}{A_{site}} \quad (3.1)$$

Where B = count of building, R = count of retail spaces, RES = count of residential uses, OF = count of office uses, and A_{site} = the area of the site in hectares.

3.6.2 Enclosure

Linear arrangements of buildings along narrow streets and squares concentrate and give shape to life in the public realm. The enclosure metric describes the degree to which these characteristics are present in the study area.

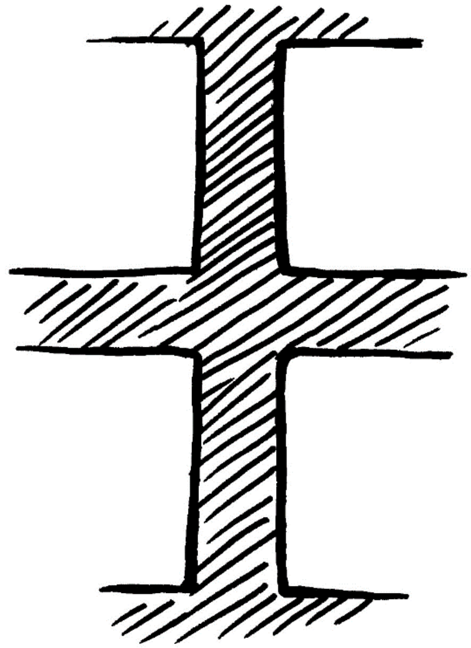

Figure 3-31. Enclosure conceptual diagram.

Enclosure is operationalized with two components:

1) the presence of a continuous streetwall along the boundaries of public right of way or square and private land, *and*

2) the size of the private realm.

Streetwall is measured by dividing the length of the edge of each block by the total length of the block edge minus gaps in which building façades fronting are not present. The larger the proportion of potential streetwall which actually exists, the higher the enclosure.

The size of the private realm is measured based on the area of all buildings and private open spaces. This area is divided by the total area of the site to find the proportion of private realm. The larger the private realm, the more concentrated the public realm and the higher the enclosure score.

The streetwall proportion and the private realm proportion are multiplied together to derive the score for the enclosure metric (*EC)* as shown in (3.2

$$EC = \frac{GS - PS}{PS} \times \frac{A_{PUB}}{A_{site}} \qquad (3.2)$$

Where GS = the length of gaps in the streetwall, PS = potential streetwall i.e. the total length of building façades, A_{pub} = the area of public realm and A_{site} = the area of the site.

3.6.3 Engagement

Buildings with decorated façades, entrances, and windows on their street-facing sides energize and engage with the public realm. The engagement metric describes the degree to which buildings interact with the street in this way.

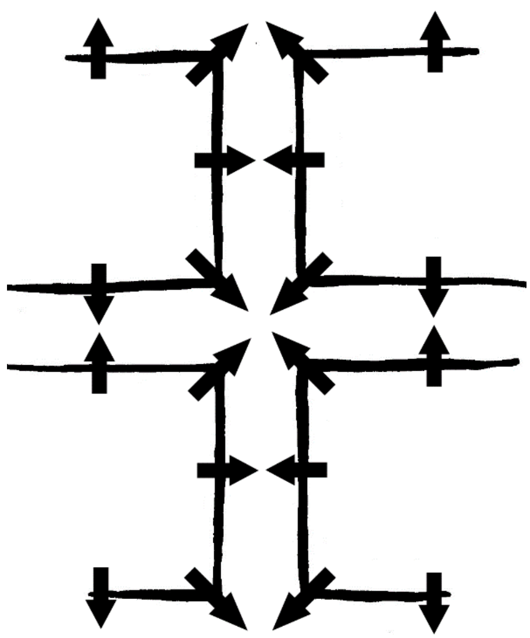

Figure 3-32. Engagement conceptual diagram.

It is operationalized with two components:

1) the total number of building entrances accessible from the street, *and*

2) the proportion of the total number of buildings which have a visible orientation toward the street.

The total number of entrances in each site is counted and divided by the area of the site in hectares to find the entrance density.

The number of street-oriented buildings is divided by the total number of buildings in the site to derive the proportion of street-oriented buildings. This is multiplied by a weighting multiplier, which is found by dividing the mean entrance density by the mean building orientation proportion among the study sample. The entrance density and the weighted building orientation are added together to find the score for the engagement metric *EG*, as shown in Equation (3.3).

$$EG = \frac{E}{A_{site}} + \left(\frac{\bar{x}\left(\frac{E}{A_{site}}\right)}{\bar{x}\left(\frac{O}{B}\right)} \right) \times \frac{O}{B} \qquad (3.3)$$

Where E = the count of entrances, A_{site} = the area of the site in hectares, B = the count of buildings, O = the count of street-oriented buildings and $\bar{x}$ signifies the mean average of the samples surveyed.

3.6.4 Lively Urban Form (LUF) Combined Metric

In order to provide a find an overall score for each site, the three metrics are combined with equal weights. Scores are weighted against the ratio of the mean component metric and the mean engagement metric score and added together to find the combined *LUF* score as shown in Equation (3.5).

$$LUF = PD\left(\frac{\bar{x}PD}{\bar{x}EG}\right) + EC\left(\frac{\bar{x}EC}{\bar{x}EG}\right) + EG \qquad (3.5)$$

Where PD = the place density metric score, EC = the enclosure metric score, EG = the engagement metric score, and $\bar{x}$ = the mean average of the samples surveyed.

In order to produce more legible results, these raw LUF scores have been weighted with the highest scoring site, CPH 1, set to 100 to find the weighted Lively Urban Form score (*wLUF*) as shown in Equation (3.6).

$$wLUF = \frac{LUF}{LUF(CPH\ 1)} \times 100 \tag{3.6}$$

3.7 Hypotheses

Based on information gathered during initial site selection, some expectations were formed about how the sites would score on the Lively Urban Form metrics. Generally, the sites have been numbered by their expected ranking from high- to low-scoring sites (CPH 1, CPH 2, CPH 3…). Other hypotheses are shared below.

3.7.1 CPH 1 – Indre By

This site is expected to score very highly on the LUF metric with its many buildings, stores, courtyards, narrow streets, continuous streetwall and historic, street-oriented buildings. The Lively Urban Form metrics were crafted in largely in reference to this place, which is used as a model for lively, historic urban centers in general.

3.7.2 CPH 2 - Vesterbro

This site is expected to score high on the LUF framework, but not as highly as CPH 1. It has continuous streetwall, historic buildings oriented towards the street, many buildings and businesses, and relatively narrow streets.

3.7.3 CPH 3 – Outer Norrebro

This neighborhood is expected to have a moderate LUF score, with a medium place-density score, a fairly high enclosure score, and a low engagement score. It has continuous streetwall, but relatively few shops. It has a mix of pre-war and post-war buildings and fairly wide streets.

3.7.4 CPH 4 - Sluseholmen

This site is expected to have a moderate LUF score. It is likely to have low place-density score with its large buildings and few businesses. Its continuous streetwall should give it a fairly high enclosure score. It is expected to have a low engagement score, with buildings generally more oriented towards courtyards than towards public streets.

3.7.5 SEA 1 – Capitol Hill

This site is expected to have a fairly high LUF score. It should score high in place density with its many businesses and mix of small and large buildings. It is expected to have a fairly high enclosure score, with its nearly continuous streetwall and high degree of built space. With the many historic buildings, which tend to be street-oriented, in the area it is expected to score fairly high on engagement as well.

3.7.6 SEA 2 – University District

The site is expected to have a fairly high LUF score. It should score highly in place-density with its many narrow storefronts hosting a wealth of independent businesses. It is expected to score highly on enclosure as well, with a continuous streetwall along the Ave, although openings in the streetwall are more common on adjacent streets. It is expected to score highly on engagement as well, with many street-oriented retail buildings and historic, ornamented apartments.

3.7.7 SEA 3 – South Lake Union

This site is expected to have a fairly low score on the LUF metric. It will likely have a low score on the place-density scale, with its few, large buildings. It is expected to score fairly high on enclosure, with more or less continuous streetwall and a large built-out area. It is expected to score low on the engagement metric, with few buildings oriented toward the street.

3.7.8 SEA 4 - Northgate

The site is expected to have a low score on all aspects of the LUF metric, with few buildings and businesses, discontinuous streetwall, large undefined open spaces, and post-war unornamented architecture.

4 Findings

The three metrics for lively urban form were applied to the eight study sites. The results of this study are presented in the following section, beginning with a comparison of basic information about the study sites. Results for each metric are then presented followed by the combined Lively Urban Form (LUF) scores.

4.1 Study Sites in Context

Before applying the LUF metrics to the study sites, contextual information was collected to provide a basis for comparing the sites. In general, all eight sites were selected to be urban, moderate- to high-density mixed-use neighborhoods. However, the context information reveals significant variation among them.

The sites include a range of neighborhood ages in both cities. The oldest is Indre By (CPH 1) in Copenhagen, with a median building year of 1800. Four sites have median building year between 1880 and 1932, and three sites have a median building year more recent than 1990. In terms of historical development patterns, Indre By dates from the era of the “walking city” which lasted until the middle of the nineteenth century, Vesterbro (CPH 2), Nørrebro (CPH 3), Capitol Hill (SEA 1) and U-District (SEA 2) date from the era of the streetcar from the late nineteenth to the early twentieth century, while South Lake Union (SEA 3), Northgate (SEA 4) and Sluseholmen (CPH4) date from the automobile era beginning in the mid-twentieth century (Jackson, 1985). All study sites include a mix of residential and commercial uses, however this mix varies substantially from site to site, with fewer than 300 dwelling units (DU) in Capitol Hill (SEA 1) and the U District

(SEA 2) and a high of more than 1300 DU in South Lake Union (SEA 3). The Copenhagen sites, by contrast, are more consistent. Commercial capacity was not recorded.

Two measures of street-grid grain size are included: intersection density and median block size. Because of the small size of the study sites intersection density is highly variable depending on the placement of the site boundaries. The study sites range widely in block size with a minimum of 4,700 square meters and a median size of 8,600 square meters. SEA 4 is the outlier with a median block size of 88,000 square meters, with a block which extends vastly outside of the study area.

Walkscore® values were also acquired for each site, ranging from 99 to 54. Three sites, Indre By, Vesterbro, and Capitol Hill all scored a near-perfect 99, while Norrebro and U District also scored in the 90's, meaning all five were "walker's paradise". South Lake Union and Northgate were both rated as "very walkable" leaving only Sluseholmen in the "somewhat walkable" category. Walkscore's algorithms are based on the number of destinations within a 10-minute walk of the origin point, meaning that places located near commercial centers tend to score well.

Table 1. Study sites in context.

Site Code	**CPH 1**	**CPH 2**	**CPH 3**	**CPH 4**	**SEA 1**	**SEA 2**	**SEA 3**	**SEA 4**
District	Indre By	Vesterbro	Norrebro	Sluseholmen	Pike/Pine	U District	South Lake Union	Northgate
Center point (Lat, long)	55.677284, 12.575793	55.668350, 12.550417	55.703591, 12.547506	55.645921, 12.551099	47.614064, -122.319621	47.659055, -122.313217	47.626976, -122.342381	47.708590, -122.321860
Main Street	Streadet	Istedgade	Tagensvej	Ernie Wilkins Vej	Pike	University Way ("The Ave")	Dexter	Northgate Way
Site Area (m2)	37500	37500	37500	37500	37500	37500	37500	37500
Median building year	1800	1890	1932	2008	1912	1923	1999	1992
Dwelling Units (n)	765	575	540	714	281	239	1329	466
Intersections (n)	9	3	2	6	3	2	2	3
Median Block Size (m2)	4700	8800	11090	6600	8480	9600	5340	88000
Walkscore®	99	99	93	54	99	95	86	87
Distance from City Center (km)	0.25	1.75	3.26	3.8	1.5	5.5	2	11.3

4.2 Place Density

The place-density metric shows that Indre By (CPH 1) is overwhelmingly more place-dense than the other study sites (Figure 4-1). It has twice as many buildings (109) and its total score (81.6 places per hectare) is 34% higher than the next most place dense site, Vesterbro (CPH 2). Meanwhile, Sluseholmen has the lowest place-density score of the group. In the same area as Indre By it has only 6 buildings and 21 total places and a total score of 5.6 places per hectare.

Sluseholmen (CPH 4) and South Lake Union (SEA 3) appear to have much in common, with low place-density counts and few retail spaces or office uses. They are also the most recently developed sites (median age 1999 and 2008 respectively) and have the highest DU totals (1329 and 714 respectively). The streetcar era sites (CPH 2, SEA 1 and SEA 2) all have relatively high place counts and roughly twice as many retail spaces as buildings.

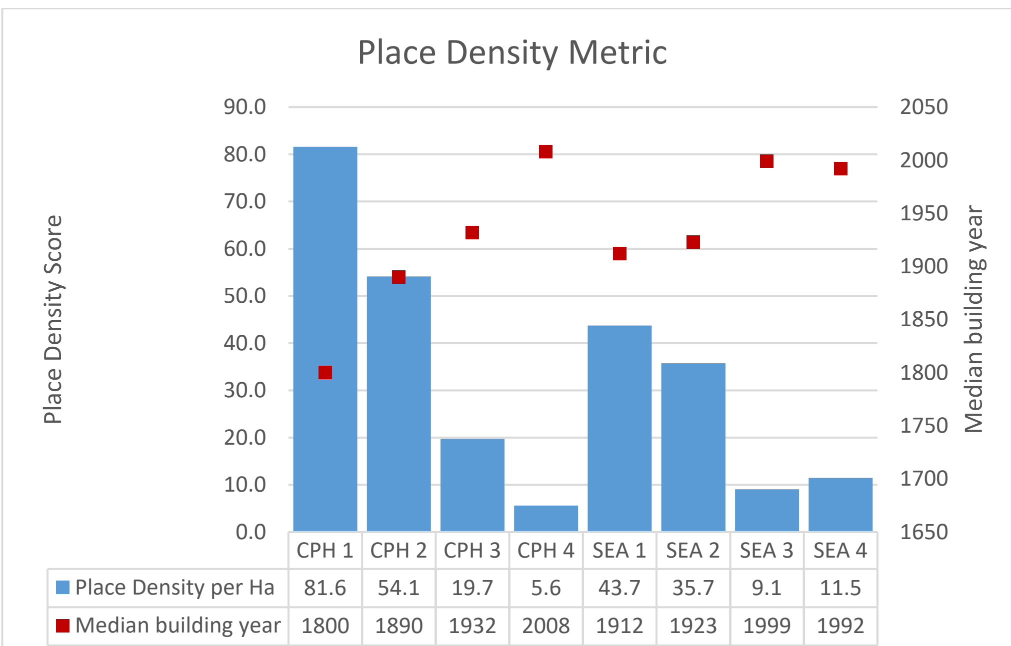

Figure 4-1. Summary of the place-density metric with median building age shown for context.

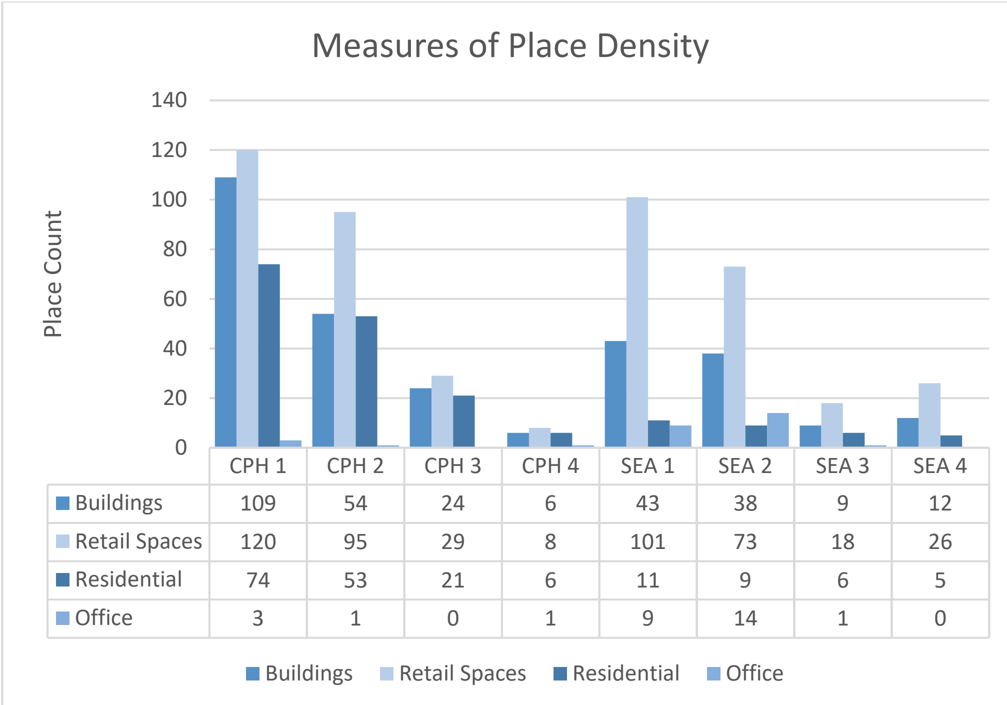

Figure 4-2. Summary of place-density measures in the eight study sites.

4.3 Enclosure

The enclosure metric shows that Indre By (CPH 1) has the highest level of enclosure (see Figure 4-3). It and all other Copenhagen sites score higher than the four Seattle sites. Indre By has the largest proportion of private realm among the study sites and nearly complete streetwall. Notably, the size of the private realm in the Northgate site (SEA 4) is two and a half times smaller than in Indre By (CPH 1).

The low private realm measure of the U District site (SEA 2) is a result of its alleys and associated spaces which were counted as part of the public realm. This is the only site to include alleys, which were counted as part of the public realm. Generally, areas with smaller blocks and more frequent intersections are thought to have a larger amount of space devoted to streets (and therefore public realm). However, in this study Indre By (CPH 1), the site with the smallest blocks and most streets, also had the smallest public realm, while Northgate (SEA 4), the site with the largest blocks and fewest streets, had the largest public realm.

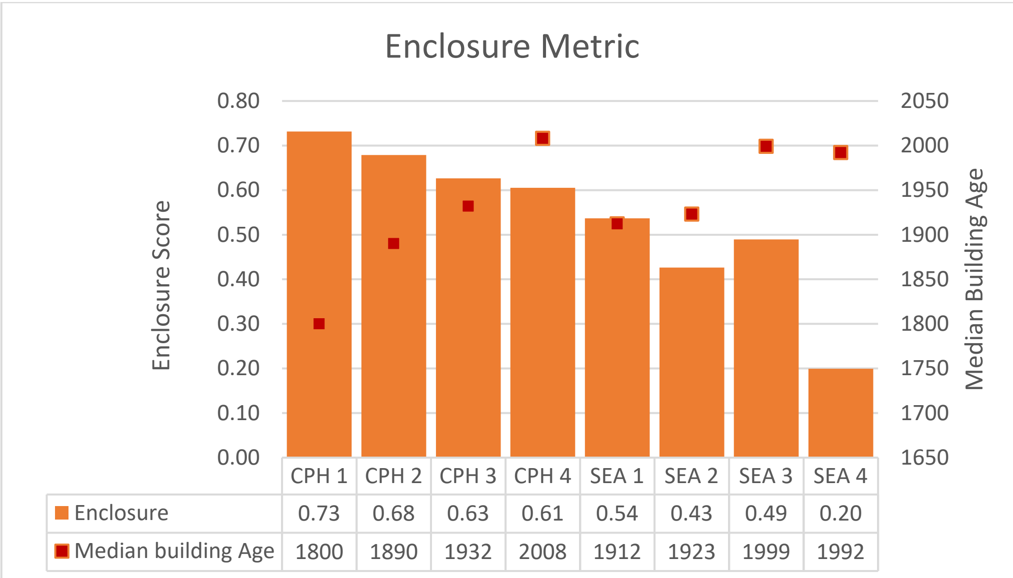

Figure 4-3. Summary of the enclosure metric with median building age shown for context.

4.4 Engagement

The engagement metric shows a distribution of scores similar to the results for the place density metric, with Indre By (CPH 1) scoring the highest. The streetcar era districts of Vesterbro (CPH 2), Capitol Hill (SEA 1), the U District (SEA 2) and Outer Norrebro (CPH 3) fall in the middle in that order. Finally, the young neighborhoods of South Lake Union (SEA 3), Northgate (SEA 4) and Sluseholmen (CPH 4) have the lowest scores. Unlike in the place-density results, Indre By scored only a little higher than Vesterbro while Norrebro scored similar to Capitol Hill and U District. Also unlike the place-density metric South Lake Union scored higher than Northgate or Sluseholmen, due to its higher entrance count.

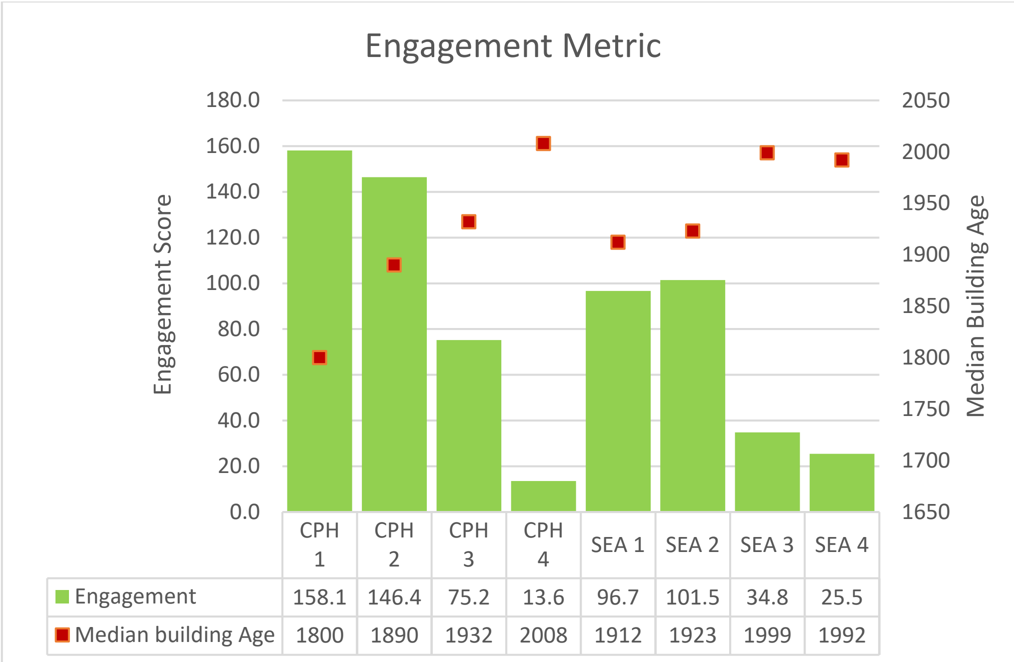

Figure 4-4. Summary of findings of the engagement metric with median building age shown for context

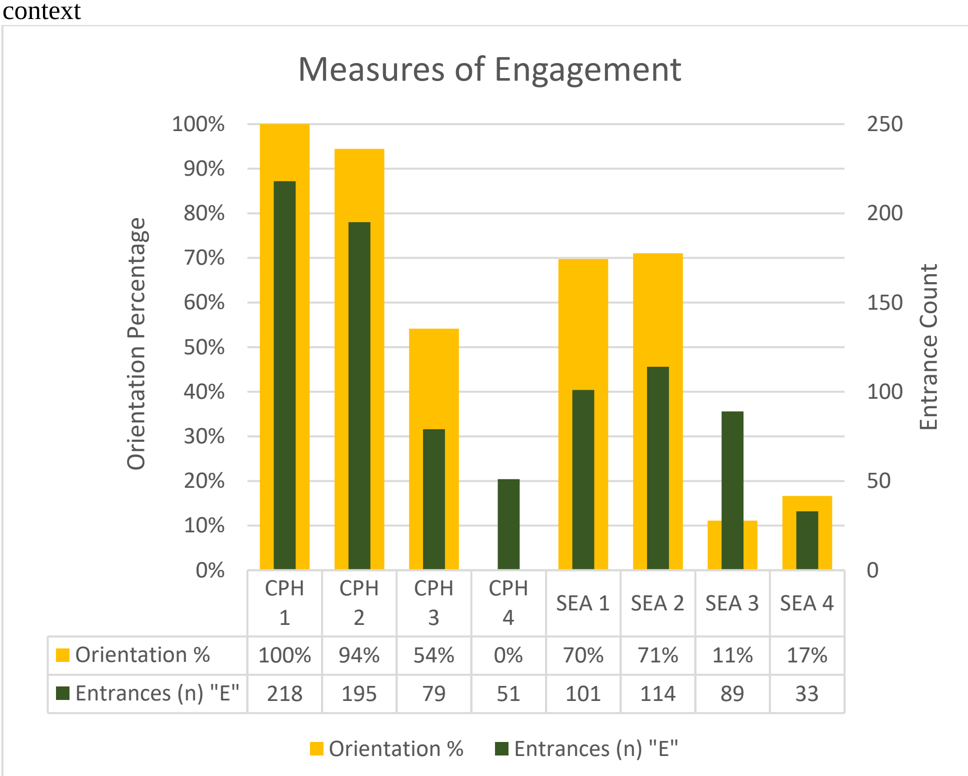

Figure 4-5. Summary of enclosure measurements of enclosure.

Both component measures of the engagement metric also show a wide range of values. The proportion of street-oriented buildings ranges from 100% at the Indre By site to 0% at the Sluseholmen site. Five of the sites are at one or another of the extremes of the scale, with only Norrebro, Capitol Hill and U District having a balanced mix of street-oriented and not street-oriented buildings. Generally, orientation proportion tracked closely with median building age, with older sites having a higher proportion and newer sites having lower proportions.

Entrance count is correlated strongly with median building age in Copenhagen sites. Vesterbro, the second oldest site, has nearly as many entrances as Indre By, despite having less than half as many buildings. The correlation is much weaker in Seattle, with South Lake Union, the site with the newest buildings, having nearly as many entrances as Capitol Hill. The Northgate site has less than a third as many entrances as U District and less than a sixth as many as Indre By. Norrebro and Sluseholmen have lower entrance counts than was hypothesized. Given the use of street-accessed stairwells instead of internal corridors for circulation within buildings it was expected that these areas would have more street entrances than the sites in Seattle.

4.5 Lively Urban Form

The results of the combined Lively Urban Form framework show a distribution similar to the place density and engagement metrics and roughly correlated with median building age. Indre By (CPH 1) has the highest score (100 out of 100), the group of streetcar era sites in the middle, and the three youngest sites have the lowest scores. The highest scoring site in Seattle is Capitol Hill (SEA3) with a score of only 60 out of 100, indicating the possibility of the major differences in level of support for public life in the urban form of the two cities. However, it is important to note that these scores have been weighted based on the mean score for each component metric, so that all three are equally valued.

Even with the weighting of the metrics to reduce the influence of enclosure, the Copenhagen sites are all lifted by their high scores on this metric. Sluseholmen in particular has the lowest place-density and engagement scores of any site, yet still scored higher than Northgate and came even with South Lake Union based on its high enclosure score. South Lake Union is affected in a similar but less pronounced manner as Sluseholmen based on its high enclosure score.

All the scores are weighted such that the highest scoring site — in all cases Indre By — receives a score of 100. A different set of sites could yield a different ceiling, or Indre By could be used as a general benchmark for the liveliest of urban form. While it is unlikely to be the highest scoring site that could be found, it provides a benchmark for urban form which supports a vibrant public life, as has been noted by many authors, including Allan Jacobs (1993) and Jan Gehl (2010).

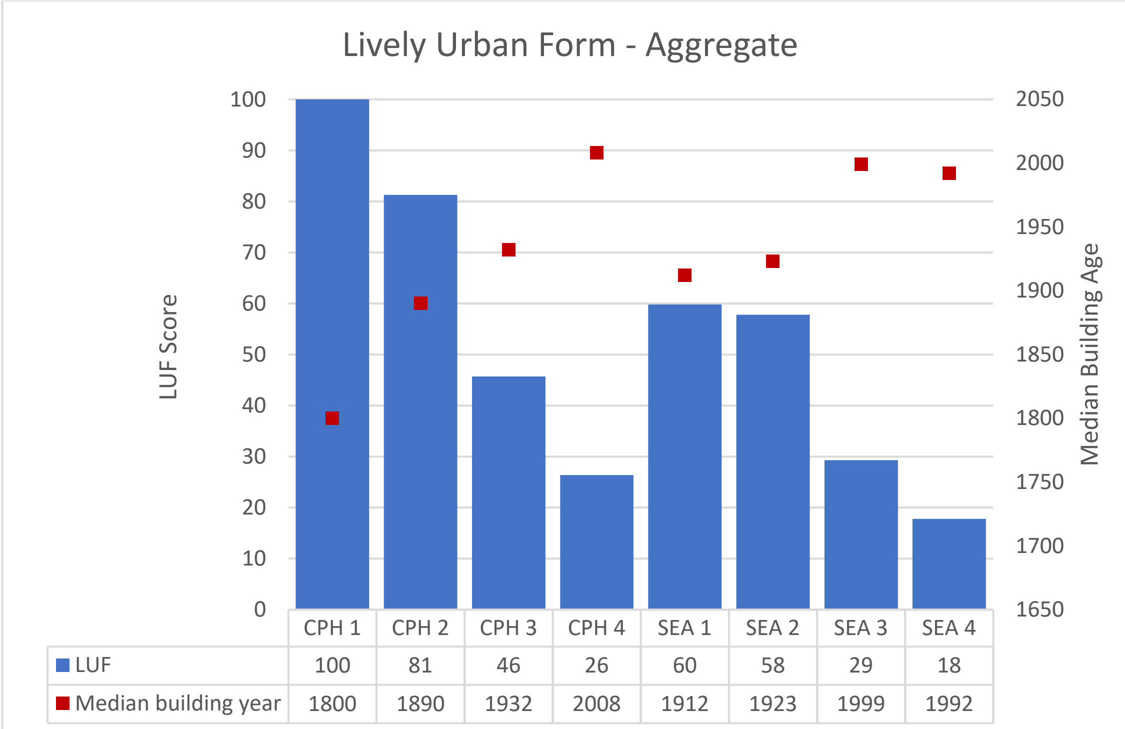

Figure 4-6. Summary of combined Lively Urban Form metric scores. Median building year also shown for context.

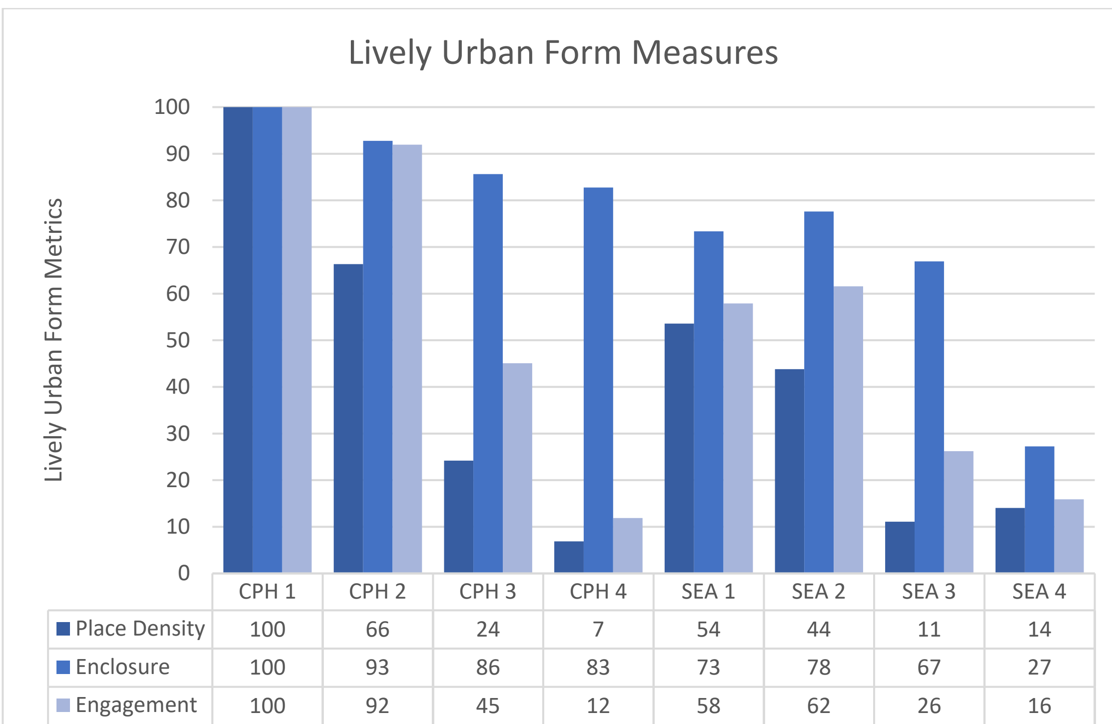

Figure 4-7. Summary of the individual Lively Urban Form metrics.

5 Discussion

This chapter records observations and interpretations from the application of the Lively Urban Form framework to the eight study sites, including information gleaned about the sites, about the metrics themselves, and reflections on the utility and limitations of the LUF framework. Finally, two additional applications of the measures are conducted as examples of potential uses of the framework.

The framework proved effective in distinguishing differences in the patterns of urban form among the sites. The results also reflected similar spatial patterns in sites of similar ages. Still, some elements of the framework were easier to apply than others, due to the mismatch between inherent complexity of the built environment and simplicity of the variables designed to measure it. A chief issue that arose was the difficulty of scoring somewhat ambiguous characteristics such as building orientation and the boundary between public and private realms.

5.1 Descriptive quality of results

5.1.1 Differences among sites

Differences between the study sites were clearly portrayed by the LUF framework. In all three metrics the Indre By site (CPH 1) scored higher than all other sites. Allan Jacobs wrote of this area "In exuberance, after an afternoon on Stroget in Copenhagen… one might exclaim, "Oh, that was a great afternoon! Stroget is a great street!" (1993, 3). Indre By's combined score was more than five times than the lowest scoring site, Northgate's. Northgate is a busy shopping area in Seattle, but one that is dominated by motor vehicle traffic. The neighborhood was described by local blogger Dan Bertolet as “hostile to human life” and by its own city design guidelines as being “unfriendly or intimidating to the pedestrian” (Bertolet 2009; City of Seattle 2009).

Individual metrics also illuminated differences between sites. South Lake Union has fewer places and only slightly more engagement than Northgate, but according to the LUF framework its form is livelier because it is much more enclosed. Likewise, the enclosure metric makes the differences in typical urban form between Seattle and Copenhagen glaringly obvious, with continuous streetwall being a rarity in Seattle and nearly ubiquitous in Copenhagen.

5.1.2 Commonalities among sites

Patterns in urban form are clearly expressed by the individual metrics of the LUF framework. South Lake Union (SEA 3) and Sluseholmen (CPH 4) received similar scores with high levels of enclosure but low place-density and engagement, delivering identical combined LUF scores. These two neighborhoods are the most recently developed of the group, and represent similar trends of redevelopment transforming urban areas from industrial and commercial to residential and office uses. The similarity of scores in these two areas is likely the result of an interaction of economic, technological, and regulatory pressures on development in their respective cities which may arise from related global influences.

Another group of sites with similar scores are Vesterbro (CPH 2), Capitol Hill (SEA 2) and the University District (SEA 3) which each scored between 44 and 93 on all three metrics. They all had about twice as many businesses as buildings, had a strong majority of buildings oriented to the street, and had between 52 and 27 entrances per hectare. This group represents areas of the study cities which developed during a period of rapid expansion along streetcar lines in the pre-automobile industrial era. Each is located outside of the downtown core and serves a secondary business district. The ability of the LUF framework to quantitatively distinguish the common characteristics of this related group highlights its utility.

5.2 Methods

5.2.1 Place-Density

Of all the metrics, the results from the place-density are the most elegant. Place-density, a count of buildings, retail spaces, and residential and office uses per hectare, is the simplest metric to calculate and it also seems to convey the least ambiguous results. The differences among the sites are expressed clearly in the combined scores and become even more so when viewed as the individual measures of buildings, businesses, and office/residential uses. Spatial representations of the measures are compelling as well.

In Figure 5-1 buildings and retail spaces are mapped for each site. The density of retail spaces is clearly visible. This image shows how this method of cataloging places within a defined area reveals information about its level of activity as well as its organizational structure.

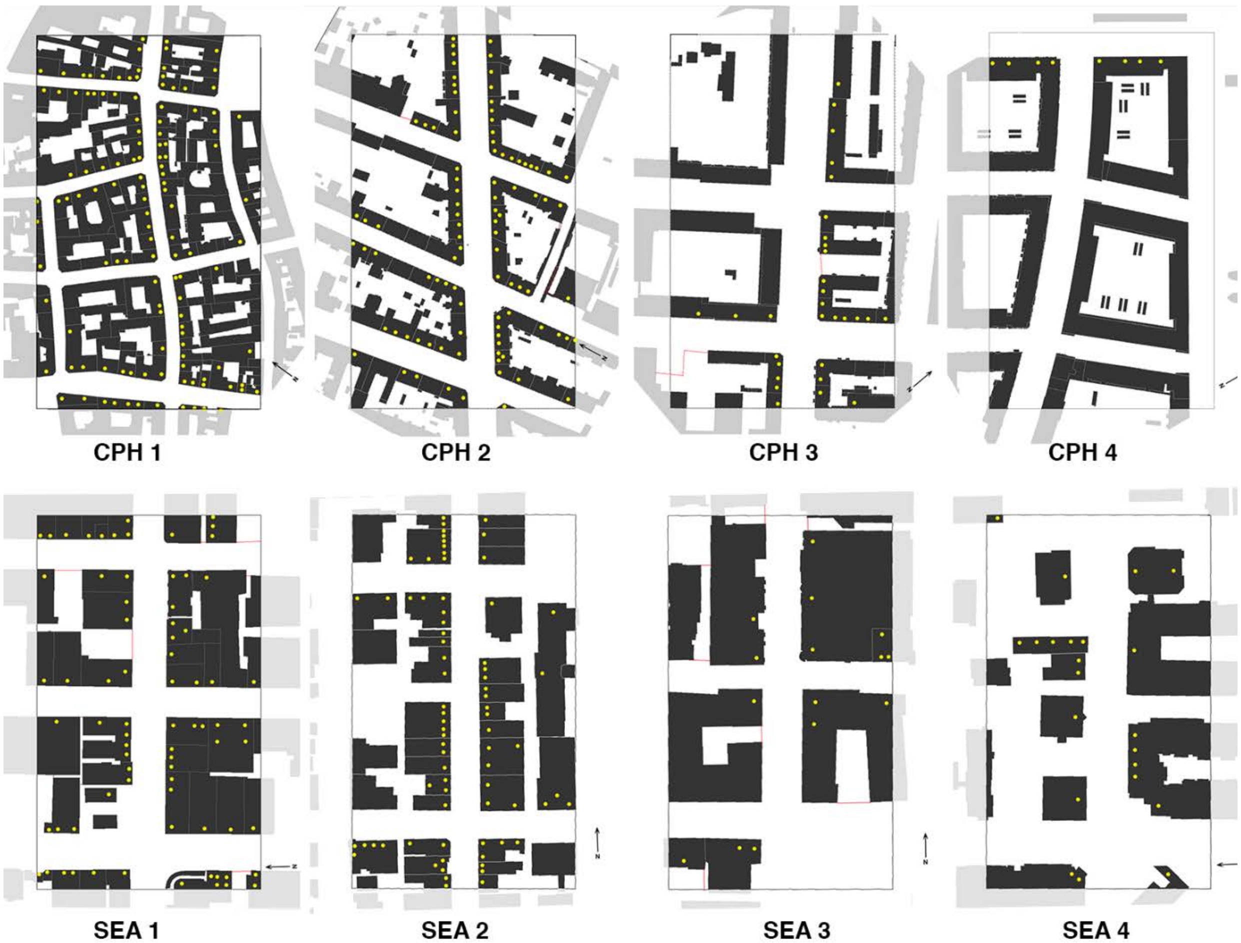

Figure 5-1. Retail Spaces marked as yellow dots.

The data for calculating place-density was fairly easy to collect. A list of commercial and residential addresses prepared for each site in GIS would have further facilitated data collection further. The presence of offices was the most difficult to determine based on Google Maps Street View, and would have benefitted most from the use of businesses address data. It is likely that the number of offices in Indre By (CPH 1) is underreported as a result. Since Indre By already had a much higher place-density score than any of the other sites it is unlikely this would have a strong impact on the results.

5.2.1.1 Open Spaces

The place-density metric formally included parks, however none were present in the study sites. Courtyards and other enclosed or "well-defined open spaces" were initially included as well, however these were removed from the scoring because

1) they are not accessible or in many cases visible to the public, meaning they have little to no impact on the quality of the public realm, and

2) courtyards or rooftop decks may sometimes have a name and a place-identity, but courtyards often merely serve as a car/bike parking lot and utility storage area.

Ambiguities in definitions became evident when considering whether rooftop decks would need to be counted as "well defined open spaces" given the original research proposal even though they have no impact on the street environment. The effect of removing courtyards and similar spaces from the place-density score did not impact the scores substantially, except to slightly reduce the scores of Indre By and South Lake Union, where respectively many courtyards and rooftop decks are present.

5.2.1.2 Residential and Office Uses

The counting of residential and office *uses* per building, rather than each residential and office unit per building seemed counterintuitive at first but worked well. Counting every single dwelling unit as a place could have overwhelmed the other elements of the score. Still, it is hard to deny that an apartment building contributes something to the public realm which a private storage building does not. Similarly, offices bring life into the public realm by attracting office workers, however the identity of each office is irrelevant to the public observer since these businesses do not attract business from passersby. The counting of office and residential uses per building allowed the metric to reflect the limited contributions of these elements to supporting public life in a way that was mathematically simple to measure.

No single-family houses were present in any of the study sites, however this method of place counting would give a relatively high score to a neighborhood composed of such building types. Further applications of the LUF framework could explore this relationship. The reduction in place-density that can occur when multiple low-density homes are replaced with a single high-density apartment building may be a clue to popular backlash against density increases. This process may be a fruitful area of future study and application of the LUF framework.

5.2.2 Enclosure

5.2.2.1 Private Realm

The measurement of the private realm was conducted by counting pixels using Adobe Photoshop. A more reliable methodology would perform this task using geometric measurements in GIS software. Areas of the study sites covered in water were counted as part of the public realm, which reduced the enclosure scores for Indre By (CPH 1) slightly and Sluseholmen (CPH 4) substantially. Although this area is not technically accessible on foot, it is understood to be part of the public realm. It not only visually accessible from the street, but boats and swimmers pass through these canals freely.

An implication of the measurement method for this metric is that programming and arrangement of the public realm does not affect its liveliness. This is emphatically not the case, as important work done by scholars and advocates for safe and lively streets have demonstrated in recent decades. The presence of automobile travel lanes, bike lanes, ample sidewalks, trees, street furniture and many other elements powerfully impact the quality and usefulness of the public realm. However, it may also be asserted, all else being equal, that narrow streets favor pedestrian travel at the expense of automobile travel due to the greater space requirements of the latter. Furthermore, streets can at least theoretically be repainted and improved at any time, while the placement and sizing of rights-of-way can persist for centuries. The ability to measure and describe the spatial characteristics of rights-of-way during the planning and building of neighborhoods is therefore of great import.

5.2.2.2 Alleys

The U District site (SEA3) is the only one to feature alleys as an element of its urban form. These presented a complication for both measurements of enclosure, as the alleys are publicly accessible but do not seem to demarcate the edge of a block and thus do not constitute streetwall. A double standard was applied in this study in which the alley space and back parking lots were counted as part of the public realm but were not counted in any way towards the streetwall measure (i.e. the width of the gap where the alley intersects with the street was subtracted from the potential streetwall length). Thus, the private realm score for the U District is the second lowest of any site. An alternate approach excluding the alley from the public realm would raise the U District's engagement score from 43 to 56 and its overall LUF score from 53 to 58 out of 100. However, it is difficult to justify excluding the alley from the public realm. Alleys are covered by a public right-of-way easement and are used for similar functions as the utility access space surrounding buildings in the parking lots of Northgate (SEA 4), which are counted as public in this study. On the other hand, utility access in the Copenhagen study sites is fulfilled by courtyards, which are excluded from the measurement of the public realm. Alleys seem to occupy a middle case between enclosed, private courtyards and open, public utility access areas. The fact that it is difficult to easily place them in the binary of public and private may be a key to their usefulness and potential problems.

5.2.3 Engagement

The label for this metric "Engagement" is not ideal. In urban design and planning contexts, the term "engagement" is more often used to refer to the public process by which the opinions of residents of a particular area are included in a design process concerning where they live. Other terms such as "interaction" "building engagement" or "porosity" may be more appropriate. The more common term in urban design literature "transparency" has been avoided to prevent confusion with the physical definition of that term which is often interpreted to mean nothing more than the presence of glass windows (e.g. Ewing 2013, 12).

5.2.3.1 Orientation

The measure of building orientation had the largest range of any measure, from 0% to 100%. It also proved to be the most problematic measure. Orientation may be the sort of complex attribute which is not easily translatable into more simple operationalized variables. The three-part test laid out in section 3.3.4 in the Methods chapter was created late in the process in an attempt to improve the replicability of the data collection.

5.2.3.2 Combination of Interval and Ratio scores

The engagement metric required the combination of a ratio (the proportion of street-oriented buildings to buildings overall) and an interval (the number of entrances). The balancing of these values to create a combined engagement score required the weighting of the two scores. This was done by adjusting the weight of each score so that the means of the scores of the eight sites would have equal weight. However, this is based on the small sample size of eight sites and may need to be adjusted in future applications.

5.3 Limitations

A quantitative approach to describing urban form is necessarily limited in the completeness of its measures and the complexity of its assumptions. Some of these limitations are discussed in the preceding and succeeding sections. However, limitations based on fundamental assumptions of the study should be addressed independently.

The LUF metrics of this study assume an urban environment composed of a few fundamental elements: buildings, discrete specialized uses within buildings, and public streets. Where these three elements are not all present, the method will not function correctly. This limitation may be most apparent if the framework were to be applied to a campus in which buildings, open spaces, and travel routes are unified in ownership and purpose. It also constrains the lower limit of the size of the study site, which should probably not bee. less than a single city block..

The LUF metrics also deal mostly with the built and open spaces on the ground plane. This approach is based on the assumption that there is a single, contiguous ground plane that is the most important part of the built environment for the person passing through on foot. This assumption is supported by the research by Hall and Gehl to show that human vision is much more perceptive of subjects at the same horizontal plane of the observer. Objects elevated more than 50 degrees above the viewer are out of the natural line of sight, hence elements of buildings above the third story tend to have a limited impact on the experience of the person walking on the street (Hall 1966;

Gehl 2010, 39-41). However, the assumption of a single identifiable ground plane is challenged in situations in which steep slots, grade-separated rights-of-way, or building terraces and elevated platforms exist. Some of these difficulties are confronted in section 5.4.2 in which the LUF framework is applied to an area with a steep slope in downtown Seattle.

Finally, it should be noted that the study sites selected provide a very limited set of circumstances in which to test the LUF framework. In this study the highest scoring site on all measures was Indre By (CPH 1), the beloved heart of one of the world's most livable cities. However, the spatial properties that translate into high scores on the LUF metrics could also be found in areas that are considered much less desirable. Slums and tenement districts are often characterized by many small buildings, continuous streetwall and a severely constrained public realm. The metrics developed in this study would likely rate these kinds of neighborhoods very highly – possibly even higher than Indre By – and to the extent that a slum *is* a lively neighborhood, this would not be erroneous. It should be remembered that LUF metrics measure spatial characteristics, not socio-economic ones. Ideally, enough kinds of urban environments would be assessed using the LUF framework to establish a more balanced group of example cases, with examples of both highly- and poorly-regarded neighborhoods on both ends of the lively urban form spectrum.

5.4 Applications

The Lively Urban Form framework may be of use to planners, developers and urban form researchers for documenting and expressing characteristics of the built environment. The following examples explore different ways in which the LUF framework could be applied to both professional and academic research.

5.4.1 Application 1 – Neighborhood Preferences and Perceptions

The first application of the LUF framework uses LUF to investigate the relationship between personal perceptions and preferences and LUF scores. Data were obtained from the Travel Assessment and Community (TRAC) project, a study examining correlations between home location, perceptions of home neighborhoods, and travel patterns in response to introduction of a new light rail system (Saelens et al. 2014). Individual respondents' home addresses were geocoded, and those locations were used to link responses to the four Seattle sites previously measured for LUF index values in this study. For this application, survey data from respondents who resided within 500m of one of the Seattle study sites were aggregated to create a set of responses related to each site. Responses for ten survey prompts were selected for comparison with LUF scores. These questions were selected to cover a few of the areas of urban life that might be influence by urban form at the neighborhood scale: perceptions of community, neighborhood attractiveness and interest, transportation modes, and walkability. Selected TRAC survey prompts are:

1) This is a close-knit neighborhood.
2) Sense of community was an important reason for moving to neighborhood.
3) There are attractive buildings/homes in my neighborhood.
4) There are many interesting things to look at while walking in my neighborhood.
5) There is so much traffic along nearby streets that it makes it difficult or unpleasant to walk in my neighborhood.

6) I like riding a bike.

7) I need a car to do many of the things I like to do.

8) The price of gasoline affects the choices I make about daily travel.

9) Stores are within easy walking distance of my home.

10) There are many places to go within easy walking distance of my home.

Capitol Hill (SEA1) had thirty-eight survey responses, U District (SEA2) had seven, South Lake Union (SEA3) had five, and Northgate (SEA4) had only three. Responses were assigned numerical values one through five, with one being "strongly disagree" and 5 being "strongly agree". These results were tested for correlation with LUF using Pearson's test. Survey response averages based on proximity to study sites are shown in Figure 5-2.

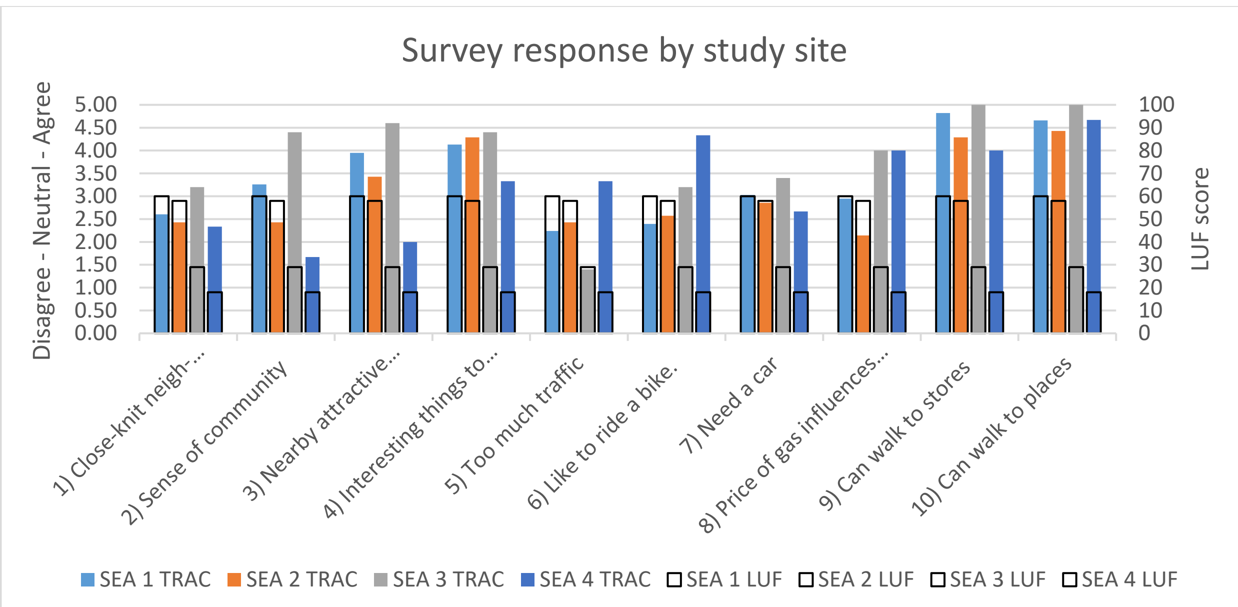

Figure 5-2. Mean TRAC survey results by prompt and study site. LUF scores shown as hollow bars.

Using Pearson's test for correlation, the strongest association between LUF and TRAC results was found to be on prompts 6) and 8), with a <u>negative</u> correlation of 0.295 and 0.230 respectively, meaning respondents from areas with livelier urban form may be less likely to report liking to ride bikes and were also less likely to be reliant on the price of gas to determine their travel habits. A weak positive correlation was found as well on prompts 3) and 9) indicating that residents of high LUF areas may have a higher perception of living near attractive buildings and being able to walk to stores. However, the correlation results for prompts 6), 8), 3), and 9) were all less than |0.3|, meaning they are only weakly associated. P-values produced by this test indicate that only prompt 6) was statistically significant, with a P-value of 0.032. All other p-values were well above the cutoff of 0.05 for statistical significance, meaning the results are likely to be caused by random chance.

Table 2. TRAC and LUF correlation results.

Prompt	1) Close-knit neigh-borhood	2) Sense of community	3) Nearby attractive buildings	4) Interesting things to look at	5) Too much traffic	6) Like to ride a bike.	7) Need a car	8) Price of gas influences travel	9) Can walk to stores	10) Can walk to places
Correlation	-0.064	0.044	0.160	0.081	-0.019	-0.295	-0.007	-0.230	0.138	-0.071
P-value	0.6468	0.7542	0.2512	0.563	0.8918	**0.032**	0.9634	0.1018	0.3256	0.6134
Observations	53	53	53	53	53	53	53	52	53	53

The application revealed several limitations. The small size of the study sites meant that almost no survey respondents resided within the study sites themselves; most responses were drawn from within the 500m radius of each study site. Furthermore, the number of responses varied greatly between the sites. This is likely the result of a mismatch between the current study and TRAC's sampling; the locations with the greatest density of participants were close to light rail stations and not overlapping the four Seattle study sites. The paucity of statistically significant associations reflects these limitations.

For LUF to be useful in the development of a study correlating neighborhood urban form with human behavior, study design would be of critical importance to ensure a large enough sample size for generating stable estimates. One potential approach would be to collect survey responses from pedestrians passing through each study site. These responses would thus be tagged to the sites themselves, rather than widely spread residence locations, ensuring sufficient statistical power to compare study sites with internal validity. Such an approach could be used to verify the theoretical basis of the LUF framework or as test associations with perceptions of attractiveness, walkability, economic activity, traffic safety or other factors.

5.4.2 Application 2 – Change over time analysis

The second application of the LUF framework tracks change in the built environment over time in a specific area.

The site chosen for this application is located in downtown Seattle and includes a single city block between 1st and 2nd Avenues and University and Seneca Streets. This block contained eight buildings until March 2017, when all but one were demolished to make way for the construction of a new skyscraper. Based on Google Street Views and design proposals for the project, the LUF framework was applied to the block as it existed until March 2017 and to the design proposals for the block as presented to the Seattle Urban Design Commission. This application will provide insight into how the new development will affect the quality of the public realm downtown. In this exercise the LUF framework was applied to the area of the single city block, a smaller area than the original study sites, but all other methods were applied exactly as previously specified.

Figure 5-3. Application 2 study site as it existed before March 2017

Figure 5-4. 2^{nd} Ave and University St March 2017. Source: author.

Figure 5-5. 2^{nd} and University St proposed. Source: Packard Chilton Architects

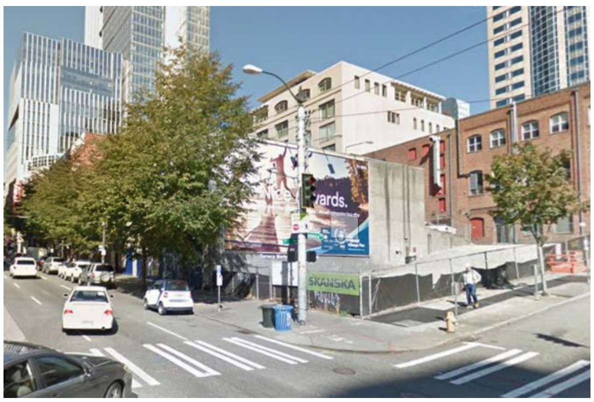

Figure 5-6. 1^{st} Ave and Seneca St Sept. 2016. Source: Google Maps

Figure 5-7. 1^{st} Ave and Seneca St proposed. Source: Packard Chilton Architects

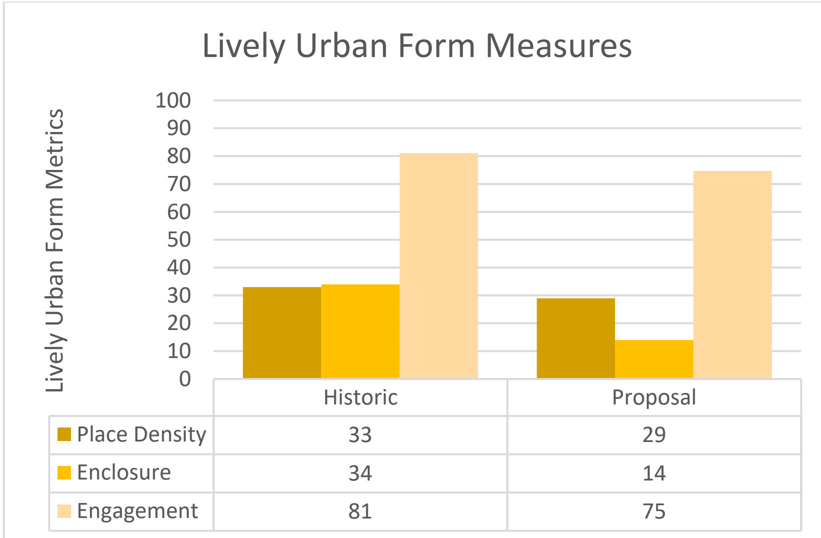

Figure 5-8. Historic and proposed LUF scores for the study site.

Overall, the liveliness of the site's urban form would drop by only eight points with the proposed design, from 49 to 41. This is largely due to the drop in the enclosure score for the site, which falls by twenty points. In place density and engagement terms, the new design is very similar to that which it replaces. The design is composed of multiple small buildings that engage with the street underneath two large towers supported by massive struts. These multiple buildings and the cafes and retail spaces they contain manage to keep the place-density score from falling too low despite the loss of seven historic buildings with narrow store-fronts. Street-level buildings and retail spaces are shown below.

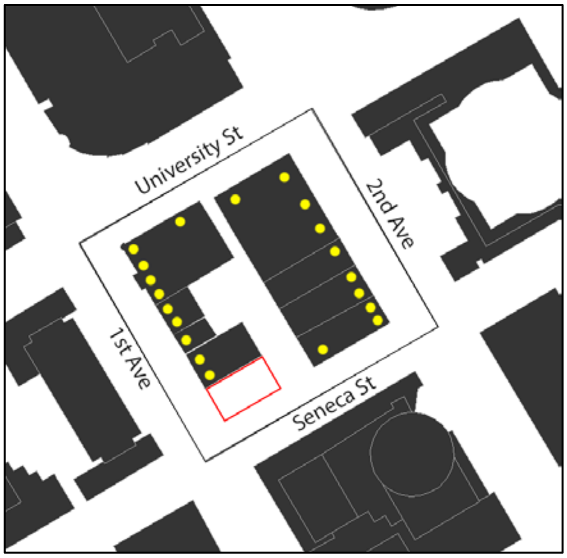

Figure 5-9. Study site historic building footprints. Retail spaces marked with yellow dots.

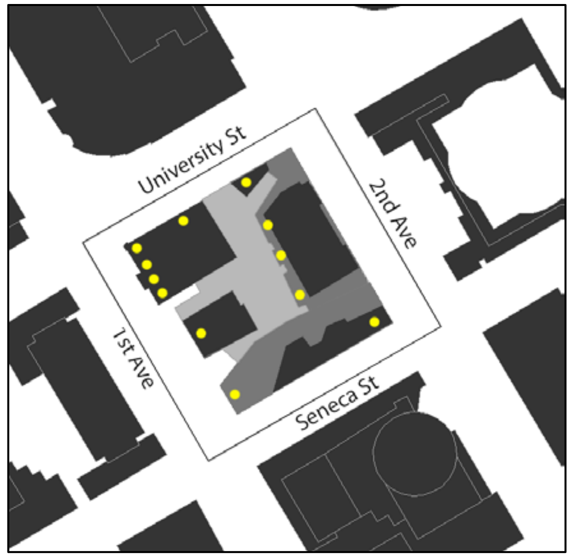

Figure 5-10. Proposed building footprints. Retail spaces marked with yellow dots.

The decrease in the enclosure score is largely the result of the number of privately-owned public spaces (POPS) in the design proposal, which due to the topography of the site, include the roofs of the buildings that front onto the low side of the site at 1st Ave. This feature of the design complicated data collection for both the private realm size and streetwall measurements and is generally a problem with two-dimensional representations of buildings in GIS data layers.

The measurements for the engagement metric, based on the entrance count and proportion of street-oriented buildings, proved more difficult to obtain with the design proposal renderings than with Google photos of the past form of the site. The application of the metric also calls into question the justification of the measurement methods. Is it more important that the street be engaged? Or is the whole “public realm”, which here includes POPS’s, equally space? Should entrance-density be calculated by area or by streetwall length? Different calculation methods have arguments in their favor.

Overall the application of the LUF framework to this block at two different points in time revealed quantifiable changes that are coming to the urban form of the area. The new design does an admirable job in maintaining the density of places, despite the parcel accumulation and demolition of historic buildings that accompanies such a project. The size of the public realm will grow and the streetwall will become somewhat less complete. Other, unmeasured factors will influence the liveliness of this area, especially the tenants of the new office high-rise above. As always, the expansion of the public realm creates the need for enough users to keep it lively. There will be fewer entrances to the street, reducing the level of interest to the pedestrian, however new public entrances in the interior public spaces may help to keep these spaces lively. This application demonstrates both the potential utility of the LUF framework for assessing change over time in the built environment as well as some of the limitations its measurements.

6 Conclusion

> *"Urban design should not be reduced to a formula. Application of a formula negates the active process of design that relates general principles to specific situations. … Furthermore, frameworks may well stress the outcomes or products of urban design, but not how these can be achieved."*
>
> — Matthew Carmona (2003, 11)

> *"If you can't measure it, you can't manage it"*
>
> — Attributed to Peter Drucker

The Lively Urban Form framework is a new method for analyzing the built form of urban environments. It isolates the spatial components which show the most radical change between the two poles on the continuum of urban form characteristics: the traditional urban form of the "walking city" and the modernist form of the "radiant city". It also illuminates some ways in which trends like New Urbanism may have influence over emerging urban form patterns.

The LUF framework is merely a tool for measuring and describing urban form. Carmona is correct in saying that as a formulaic method it is blind to the process and art of urban design. If LUF metrics were incorporated into zoning requirements they might become just another in the series of hoops for developers and architects to jump through; designs would superficially cater to its narrow and necessarily incomplete measurement protocols. Still, the current age is one in which metrics dominate decision-making in nearly all aspects of society, from nutrition to education to transportation. Importantly, their use in the real estate, construction, and public policy fields mean they determine, at least in part, how cities are built. In such an environment, it behooves urban designers and those who care about urban design to have tools available to measure and describe with precision the environments they value, to analyze and replicate those environments which work best and to pinpoint the differences between a place that works and a place that seems like it ought to work.

Such tools would empower citizens, public servants, and builders to elevate the qualities they value in the built environment to a more even playing field with the dictates of dwelling unit counts (DU/acre), road levels of service (LOS), returns on investment (ROI) and price per square foot. The purpose of a metric is to ease the communication of what is valued, to allow tradeoffs to be weighed in context and to empower advocates to use hard data in backing up their claims. To the extent that this thesis has made progress in the development of such a tool, or has laid groundwork for future work to develop precise, efficient, reliable ways to communicate different qualities of the built environment, the author would consider it a success and a worthwhile endeavor.

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