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ENERGIZING STREET LIFE OF URBAN NEIGHBORHOODS: QUALITATIVE NARRATIVES VERSUS QUANTITATIVE METRICS

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Abstract
This study examines a multitude of built environment attributes that potentially work together to energize urban neighborhood street life. It analyzes the impact of mixed-use and street network arrangements on pedestrian presence in the public realm. The study investigates pertinent land use and street network indices as well as spatial analysis techniques that rationalize active street configurational requisites. Mixed-use evenness and distribution, street network connectivity, and space syntax tools are explained with an eye on their utility in planning and designing active urban streets. The analytical approach of this study shifts the discourse from a focus on aesthetic considerations of the built environment to an integrated theoretical framework that underscores the dialectical dynamics between built environment and individuals. The study ultimately aims to establish a planning/design agenda that potentially guides the assessment and development of active urban neighborhood streets.
Keywords: Neighborhood design, mixed-use, urban grain, smart growth, street network walkability, space syntax, active streets

1. INTRODUCTION

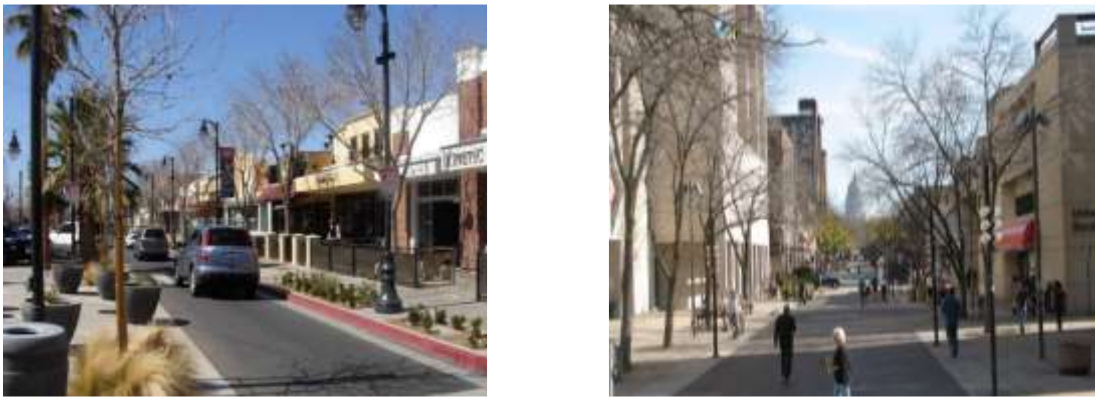
The increased reliance on the private automobile as the dominant mode of transportation has disfigured the image and function of streets in modern cities. The latter have been transformed from the traditional monocentric to polycentric development models that substantially altered the close-knit urban fabric of traditional cities. City streets have lost their role as incubators for socioeconomic and cultural functions and were more or less converted to conduits for motorized traffic that connect dispersed urban and suburban nuclei of modern metropolises. Technological advances in transportation and telecommunications facilitated such rapid transformations and eventually suffocated the pedestrian vitality of city streets (Lang, 2017; Kashef, 2017; 2018). The notion of active urban streets has surfaced in the literature over the past few decades and generally aim to highlight the planning/design strategies that would regenerate the significant role of streets in city life (Fig. 1 & Fig. 2). It has propelled real-life improvements of many downtown and neighborhood streets in cities worldwide.

The revitalization of main streets has probably acquired more steam due to the tremendous growth in digital smart city technology. The development of wireless mesh networks and broadband internet applications with 5G and 6G capabilities have provided locational flexibility for corporations not only in the same city or country but across the entire world (Mitchell et al., 2013; Lytras and Viszizi, 2021; Kashef et al., 2021). A growing segment of high-tech professionals seem to have developed an overwhelming interest in the vibrant and active street lifestyle of urban neighborhoods. Due to the varied time schedules and increased leisure time by virtue of using technology in work and business transactions, many people are currently seeking the social and cultural experiences of compact, mixed-use, and well-connected streets of traditional built environments. High-tech giants like Amazon and Apple are shifting their research and development operations to city cores because many of their employees favor urban lifestyle over sedentary suburban living. Mixed live, work, and play arrangements transpired because of high-tech companies moving to urban areas. Street improvement schemes have found their way in cities official plans to compete on a global scale for foreign investments, which are perceived as critical for the economic and social prosperity of countries (Kashef, 2016).

a. Via Toledo, Naples

b. Via Del Corso, Rome

FIGURE 1 - TRADITIONAL ACTIVE STREETS



a. Lancaster Boulevard, California

b. State Street, Washington, DC

FIGURE 2 - MODERN ACTIVE STREETS

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2. STUDY METHOD

This study offers a critical approach that integrates a broad array of qualitative design frameworks and quantitative metrics that assess the impact of land use mix, urban concentration, neighborhood grain and street network configurations on pedestrian movement. It juxtaposes recent literature arguments, empirical investigations and established theoretical frameworks to underline the built environment ingredients that energize street life and enhance neighborhood vitality. Land use configurations and street layouts are viewed in this study as the embodiment of social, economic, and cultural experiences that create vibrant streets and enhance urban neighborhood vitality. The inductive analytical method of this study highlights the uniqueness of literature arguments that work in tandem to underscore the associations between built environment and pedestrian flows.

3. LAND USE AND STREET NETWORK

Except for military towns (bastides) and few other historic examples, pre-modern cities tended to grow somewhat organically with building uses and street networks evolving as a reflection of residents' needs and power balance in society. The grand baroque developments in major European cities disrupted this organic growth and projected the power visions of the ruling elite. However, Baroque interventions did not dismantle the inherited cities and superimposed their larger-than-life spatial visions on the medieval/renaissance urban fabric. The mishmash of medieval, renaissance, and baroque developments precipitated what's widely recognized today as traditional cities (Kashef and Shafie, 2020). The latter juxtaposed the irregular fabric of medieval cities with the classic architecture of the renaissance and the spatial clarity of Baroque street networks.

The traditional city integrated different uses and street patterns within a geographically limited urban space that can be traversed on foot and limited forms of horse-drawn carriages (Kashef, 2007, Southworth and Ben-Joseph, 2003; Ellin, 1995; Broadbent, 1990). The spatial and visual contrasts as well as the functional conveniences of the traditional city structure are currently invoked as models for mixed-use and livable city spaces. The latter fit perfectly well with the romanticized postmodern image of livable streets; people strolling or biking up-and-down, chilling out in cafes, socializing, buying a loaf of bread from the bakery, walking their kids to school, and immersing themselves in the busy, yet enjoyable city ambience. The industrial vigor of the 19th and twentieth centuries had obnoxious effects on traditional city fabric, which became polluted with smoke from belching chimneys and torn apart by industrial sites, railyards, and slums for low-wage factory workers (Fig. 3). The mood at the time was anti- traditional cities including mixed uses, busy street environment, and high populations densities. Theorists, planners, and architects extended visions for garden cities and exclusively zoned suburbs as healthier living alternatives to traditional cities (Scott and Storper, 2014; Mumford, 1961; Vance, 1990; Hall, 1996). Zoning was enacted and cities sprawled into separate enclaves for residential, industrial, office, commercial, and other designations that accompanied the emergence of car-dependent polycentric metropolises. It has regulated development and unraveled some of the complexities, and inconveniences of traditional built forms. However, zoning regulations created their own set of woes and eliminated the street vitality that was shaped by the mixed-use and the tight urban fabric of traditional cities (Kashef, 2008). Advancements in smart telecommunications made it possible to regenerate the vitality of traditional city streets without the negative externalities associated with the turn of the century cities. Consistent broadband and reliable wireless communication networks have disentangled labor-intensive components of multinational service and industrial operations from creative research and development centers. The latter mostly retain high-tech employees with distinct interest in urban lifestyle, mixed-use, and walkable streets. The bulk of this paper operationalizes the impact of mixed land uses and street network configurations on urban neighborhood vitality. It provides in-depth analytical review of quantitative measurements that not only assess but also aid the design and planning of active built environments.

a. Chicago Street during normal hours

b. Chicago Street during rush hours

FIGURE 3 - TRADITIONAL CHICAGO THOROUGHFARES AT THE TURN OF THE 20TH CENTURY
(Detroit Publishing Company/Library of Congress: https://www.chicagomag.com/city-life)

3.1. Mixed-use built environments

Mixed-use as a term has been extensively referenced in the urban design literature to describe developments that combine residential, commercial, employment and other related functions. The term has become more of a bandwagon phrase used to invoke the aura of urban vitality that is often associated with traditional cities and most recent Neo-traditional views and New Urbanist developments. However, urban vitality is not simply achieved by placing or sowing these functions in close geographic proximity and inevitably anticipating or harvesting pedestrian activity and street livability.

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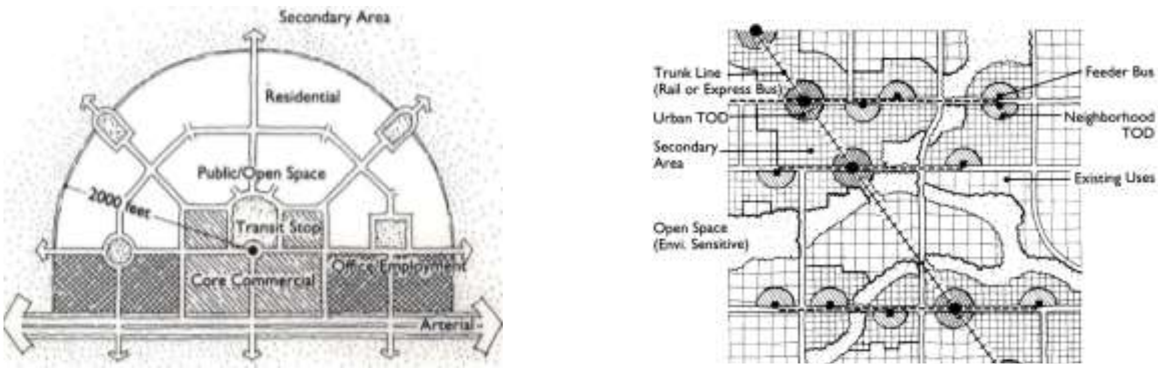
Jacobs (1961) has maintained that vibrant cities need a rich mix of social classes, home tenures, work and production facilities, population concentration, and a broad range of old and new buildings. She used the term “functional diversity” in lieu of mixed uses to highlight the need for primary and secondary urban functions that ensure that a critical mass of people would occupy the street space at different times of the day and for different purposes. According to Jacobs, residential, retail, education, recreational and employment are primary functions that provide daytime street activity while lodging, restaurants, entertainment, and commercial functions offer opportunities for evening and nighttime action. Grant (2002) indicates that functional diversity necessitates locational fit and physical integration that generate pedestrian activity and create what Hillier (1996) calls the movement economy. In that regard, pedestrian activity or movement is purposeful and inextricably linked with income and revenue generation possibilities of street functions. TND (Traditional Neighborhood Design) and TOD (Transit Oriented Development) have been introduced by New Urbanism as models of mixed-use developments (Fig. 4). These promote mixing of home tenures (single-and- multi-family) as well as live, work, and play configurations planned along transit corridors with population density gradients from high near transit stations to low on the development periphery (Calthorpe, 1993, Kelbaugh, 2002, Cervero et al., 2004).



a. Neighborhood Layout

b. Regional Structure of TODs.

FIGURE 4 - TOD: TRANSIT ORIENTED DEVELOPMENT
(CALTHORPE, 1993)

Various empirical studies have attested that higher population densities and balanced mix of residential, commercial and employment activities facilitate the development of active travel modes such as walking, biking, and transit (Ewing, 2004; Ewing and Cervero, 2010, Gehrke and Clifton, 2016; Saelens et al., 2003, Handy, 2004; Handy et al., 2004; 2008, Kashef, 2011). A handful of algorithms have been developed to measure the land use functional balance, intensity and physical adjacency requirements that enhance pedestrian activity. The entropy index was employed in measuring the distribution and/or evenness of seven mixed-use categories in various built areas. The results were normalized between the values of zero to one. Not only that higher entropy index values almost always reflected a richer mix and diversity in land use categories but were also positively associated with higher pedestrian activity (Frank and Pivo, 1994). Manaugh and Kreider (2013) articulated the statistical formula of the entropy index as:

$$\frac{-\Sigma(A_{ij}\ln A_{ij})}{\ln N_j}$$

Where:
$A\ ij$ – Percent of land use I in census tract j
Nj – Number of represented land uses in census tract j

Sung et al. (2015) introduced a nuanced entropy assessment (LUM) that can be used in less regulated built environments. Building uses in such areas tend to change overtime without being recorded in official GIS maps or building permit registry. As shown in the statistical formula below, LUM considers as built gross floor area of each use rather than land area. The higher index scores (up to 1) point to perfect evenness or equal distribution of land use categories.

$$LUM = \sum_{i=1}^{n} \frac{(P_i * lnP_i)}{ln(n)}$$

Where:
Pi is the proportion of building square footage of land use *i*
n is the number of land uses.

The entropy measures seek land use heterogeneity through equal percentages of multiple functional categories (usually 7). However, the concept of even land use distribution as a corollary for urban vitality overlooks the functional diversity and complementarity of uses articulated in various studies as a crucial factor for predicting travel behavior and pedestrian activity (Hess et al., 2001; Ewing and Cervero, 2010; Gehrke and Clifton, 2016; Mavoa et al., 2018). Cervero (1989) introduced the dissimilarity measure to compute the dispersion of land use categories in mixed-use developments. While entropy reveals the balance or evenness of land use types in mixed-use areas, the dissimilarity index measures the land use variety among contiguous developments. This metric predicts travel patterns between complementary uses such as residential, retail, education, employment and other support functions (Kockelman, 1997).

$$\text{Dissimilarity index} = \text{mix index} = \sum_k \frac{1}{K} \sum_i^8 \frac{X_{ik}}{8}$$

Where:
K is the number of actively developed hectares in the tract
X *ik* is 1 if the central active hectare's use type differs from that of a neighboring hectare, and 0 otherwise.

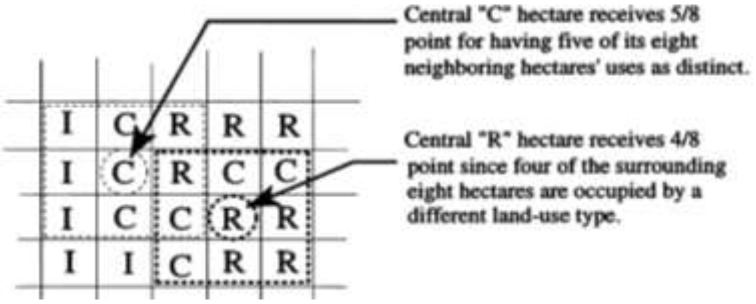


FIGURE 5 - DISSIMILARITY INDEX POINT CALCULATIONS
(Source: Kockelman 1997)

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The dissimilarity index for marked blocks C and R (Fig. 5) is calculated by adding the number of adjacent blocks with a different land use divided by 8. Each of the 8 adjacent blocks that contains a land use dissimilar from the marked blocks earns one-eighth of a point. The overall dissimilarity index of an urban tract is computed as the mean arithmetic across all blocks incorporated in the tract. The results of dissimilarity computations range from 0 (single use areas) to 1 for rich land use diversity. Kockelman (1997) also pointed to the island effect phenomenon that transpires due to the concentration of some land use types such as commercial, office or government facilities in one block or a group of city blocks (even as surrounded by other mixed-use functions). Pedestrian activity gets internalized in and around such use concentrations, which also dictate the provision of massive parking lots that further the split between complementary functions. Use concentrations such as these discourage walking across different city blocks and reduce the overall vitality of mixed-use centers. As with other entropy measures, the dissimilarity results at times misrepresent the land use diversity in real-world cities. Though land use regulations in some cities assign one function for distinct properties, other cities allow mixed uses in the same property or building either horizontally or vertically. Fig. 6 illustrates a proposed development in Brooklyn, New York that combines residential, commercial, office, and hotel uses in the same property. Developers often merge a number of adjacent properties, thereby creating large-scale developments, which may also integrate various home tenures and income groups. Large-scale, mixed-use developments in such cases get approved through special permits or variances to generate rich functional diversity. In many other cities, functional diversity accrues overtime due to relaxed building codes that propel unauthorized land use modifications in response to user needs and market economics.

However, unregulated property markets such as these may produce less functional diversity due to use concentrations and internalized pedestrian travel within a limited number of urban blocks or one megastructure. Hoppenbrouwer (2005) illustrated the various combinations of vertical mixed-use configurations with commercial and office spaces occupying lower floors and diverse residential uses in the upper floors (Fig. 7). Empirical studies in Seoul revealed that diversity of housing types and tenures may generate more pedestrian travel than mixed-use development tracts that accommodate five or more different use categories (Sung et al., 2015). Further empirical studies are still needed to develop accurate mixed-use algorithms. This study recommends cross referencing all available indices in order to obtain more representative results.

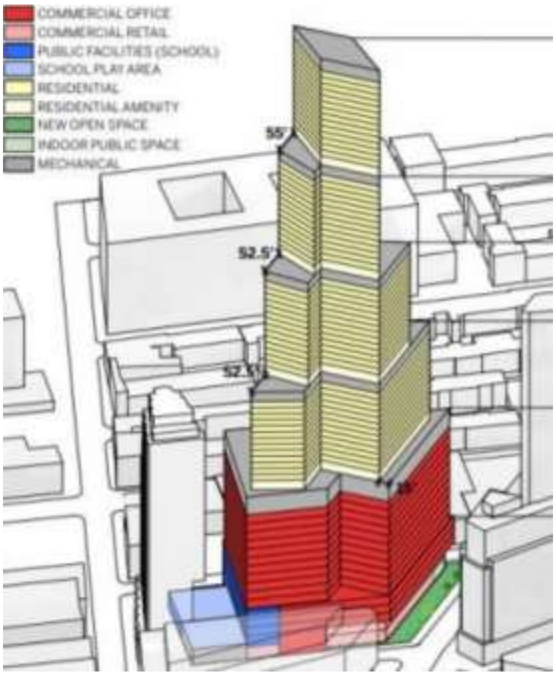


FIGURE. 6 - MIXED-USE DEVELOPMENT PROPOSAL IN DOWNTOWN BROOKLYN BY SKIDMORE OWINGS & MERRILL (NEWYORKYIMBY, 2018)

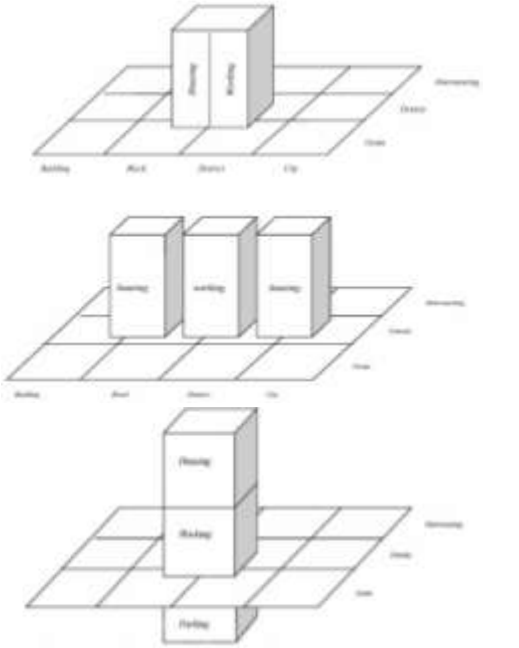


FIGURE 7 - DIFFERENT MIXED-USE CONFIGURATIONS (Source: Hoppenbrouwer 2005)

3.2. Concentration versus density

Various empirical studies around the world have found positive correlations between higher population densities in mixed-use settings and pedestrian flows. Their results corroborated Jane Jacobs's assessment of 100-200 dwelling units per acre as the recommended density for active street environment (Choi and Sardari, 2012; Sung et al., 2015; Berhie and Haq, 2017). Concentration, on the other hand, is not a reference to population density per se; it incorporates a complex array of development features that brings people to streets at different times of the day and for different purposes. Urban planning studies differentiate between overcrowded, densely populated areas and livable compact built environments. The term "compact," is operationalized as a geographically bound urban sector that accommodates a wide spectrum of social classes and diverse, yet complementary live/work/play functions, conveniently connected by motorized (mass transit and cars) and non-motorized modes of travel (walking/biking). The social experience in such compact urban developments is enhanced due to increased pedestrian flows and the accompanying sense of safety and vitality of street life. With built-in sustainability measures, compact urban developments encourage the adaptive reuse of obsolete functional arrangements and built forms. Recycled uses generate a mix of old and new buildings, promote localized business ventures, and reduce the impact of class segregation (Ewing, 1997, Dutton, 2000; Schwanke, 2003; 2004; Kashef, 2009a; 2009b; Bramiana et al., 2017; Kashef and Shafie, 2020). Based on her observations in New York and Toronto, Jacobs estimated that a mix of six-story walkup apartment complexes and twelve to fourteen story buildings would generate the critical mass required for animated street life. She asserted that such concentrations can be achieved in various ways using heterogenous built forms rather than standardized and formulaic solutions of modern planning (Jacobs, 1961; Sewel, 1993; Kashef, 2007).

Spatial concentrations in smart growth and the New Urbanism literature are envisioned as clusters of compact high density mixed-use centers and medium density subcenters that are connected by energy efficient movement corridors (Fig. 8). Low density developments in smart growth scenarios spread linearly along the movement corridors with access to transit lines that interlink mass transit hubs in the high and medium density centers and subcenters (Blair and Wellman, 2011; Duany and Talen, 2002; Ye et al., 2005; Jun, 2004). Centers and subcenters in such urban agglomerations accommodate more than 80% of the population with densities ranging from 60-80 dwellings per acre. These typically encompass mixed-use developments planned along connected street networks with direct access to light rail and bus transit hubs. Street networks are designed to provide pedestrian movement flexibility along short, inter-connected blocks that accommodate live/work/play functions. Concentration in the centers and subcenters of smart growth developments is an essential quality of livable streets. It brings together an array of complementary land uses that sustain pedestrian movement and provide impetus for other modes of travel including biking and mass transit. Small businesses primarily rely on street pedestrian flows; various studies have pointed to their potential in enhancing coexistence and social encounters, which eventually contribute to heightened sense of community (Ozbil et al., 2015; Kashef, 2009a). Smart growth developments offer residents a broad range of living densities and housing lifestyles; from high to medium densities in the centers and subcenters to diverse suburban home configurations (8-12 dwelling units per acre of detached, semi-detached, and multifamily). Low-density suburbs are allowed to develop along transit lines within walking distance from stations.

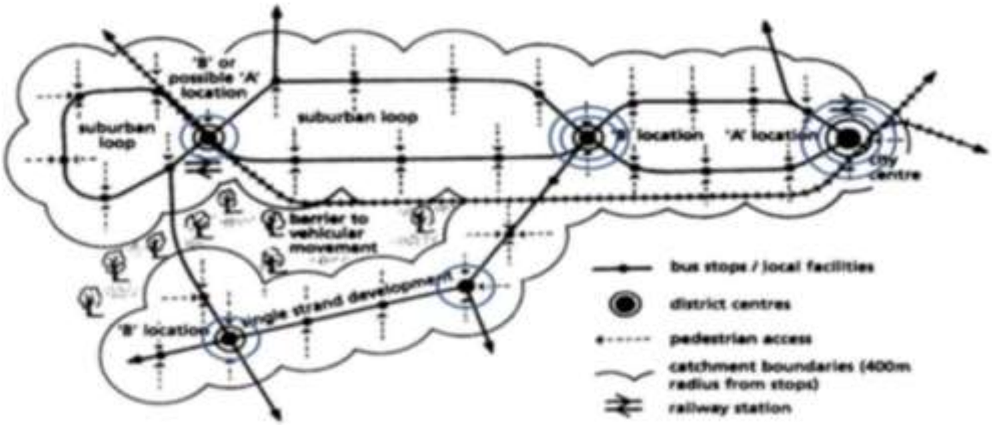
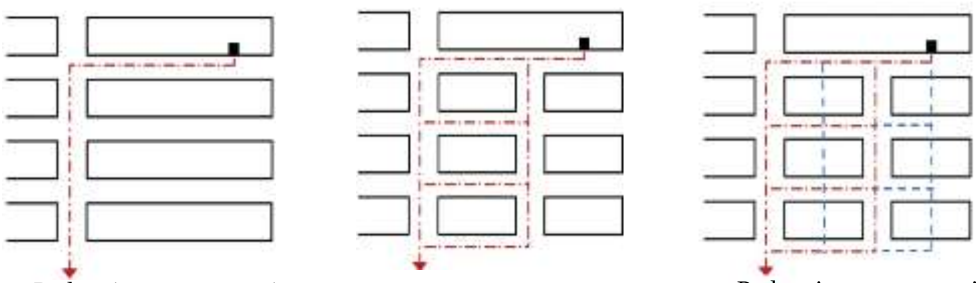


FIGURE 8 - TRANSIT CENTERED SMART GROWTH SCENARIO

3.3. Neighborhood grain and street network

From the Greek polis until modern cities, gridiron streets have provided the most effective approach for land subdivision, annexation, ownership transfer, property development, and growth possibilities. Movement flexibility, connectivity, and expandability are just few of the gridiron advantages that made it the street network of choice for small towns and great cities. New Urbanism, smart growth and resilience planning movements have underlined the pertinence and capacity of traditional gridiron street networks to meet the demands of contemporary cities (Duany and Zyberk, 1991; Katz, 1994; Krier, 1998; Dutton, 2000; Kashef, 2007). Recent empirical research often ranked the flexibility and connectivity of street networks on a score gradient from 1 for perfect gridiron till 0 for non-gridded networks with cul-de-sacs (Boarnet et al., 2011). Various studies have noted the association between urban grain (block size/street geometry) and urban vitality. Small and well-connected neighborhood blocks are often noted as adjoining features of high pedestrian flows and socioeconomic vitality (Rowley, 1996). Jacobs (1961) offered a simple illustration that demonstrates the increased flexibility of movement through fine grain urban blocks.



a. Pedestrian movement in long neighborhood blocks

b. Pedestrian movement in short neighborhood blocks

c. Pedestrian movement in short blocks with alleyways in-between properties

FIGURE 9 - COMPARISON OF PEDESTRIAN MOVEMENT WITHIN SHORT AND LONG NEIGHBORHOOD BLOCKS

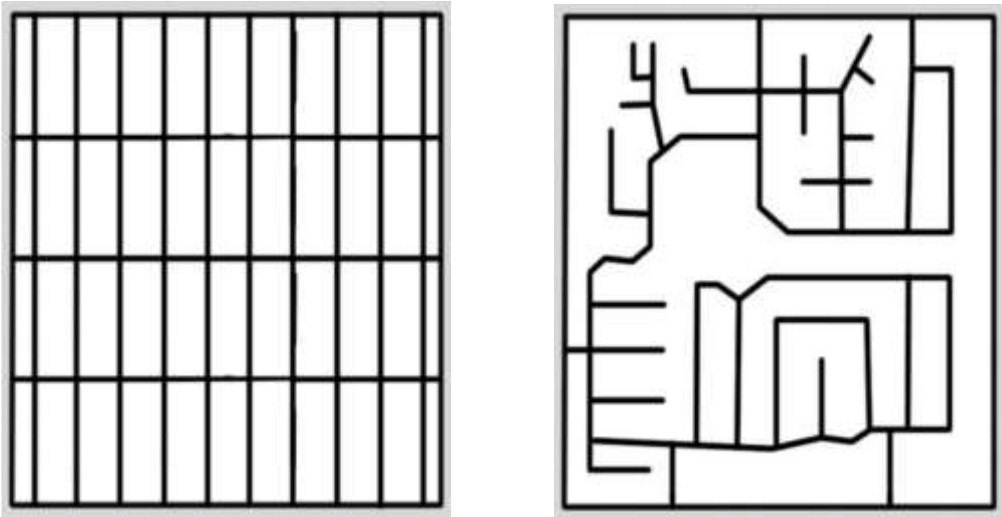
Street pedestrians can crisscross pathways and use alternative routes, thus maximizing social encounters, safety, and economic exchange possibilities for street retail and service outlets (Fig. 9).

The square blocks of Philadelphia (400 feet) have become very successful with the alleyways in-between buildings that split them for pedestrians into 200 feet blocks. Jacobs also referred to the evident decline of some Philadelphia neighborhoods that eliminated alleyways and authorized new buildings to block some streets, which eventually extended block lengths to 700 feet (Jacobs, 1961, 185). Recent empirical investigations that measured pedestrian flows in various cities and neighborhoods have recommended block lengths ranging from 300 to 600 feet or corresponding block size in acres (Handy et al. 2003; Dill, 2004). Street network indices that measure the grain of an urban sector include the block density, intersections density, and street density (Kashef, 2011; Dill, 2004; Cervero and Kockelman, 1997). The block density index simply measures the number of blocks in a defined unit area of the city. Intersections density index assesses the movement flows throughout the network by calculating the number of three-and-four-way intersections. Street density represents the cumulative length of street links per unit area of urban development. The higher number of blocks, street intersections, and street lengths per unit area of urban development tracts denote a finer grain and improved accessibility and pedestrian movement (Dill, 2004; Ewing, 1996). Connected node percentage and connectivity index are probably the most frequently used urban grain measurements. The first measures the ratio between open street intersections to all intersections plus dead ends; values above 50% define street networks with high levels of accessibility and pedestrian movement flexibility (Dill 2004).

The connectivity index value for perfectly open, square gridded street networks is around 2.5. Urban sectors with scores above 1.5 signify well-connected street networks. It is primarily calculated by dividing the number of street links by the total number of street intersections and cul-de-sacs. Case studies from around the world confirmed the positive correlation between high connectivity measurements and increased levels of pedestrian activity (Ewing, 2014; Frank et al., 2005, Kashef, 2011). The example below demonstrates the difference in connectivity between two tracts of the same size (one square mile) but with different street network characteristics (Fig. 10). Tract A boasts a perfectly open grid with well-connected rectangular blocks. It manifests a high level of connectivity (2.0). Tract B, on the other hand, is rife with dead ends and lower number of blocks, thereby resulting in disconnected built environment and pedestrian pathways.

3.4 Network geometry and space syntax

The analytical tools of street network geometry and space syntax include route directness, connectivity, and integration. Route directness relates to the geometric quality of the network and compares the cumulative length of walking distances along the streets of an urban tract with its counterpart in straight line segments of a perfect grid (Marchall, 2004; Hess et al., 2001). Space syntax delineates a set of spatial concepts and principles that underlie human interaction in the built environment (Hiller and Hanson, 1984). It aims to find the most effective street network configurations that optimize land use allocations and facilitate movement through urban space. Hillier argues that urban vitality is shaped by the relations between movement and the structural layout of local districts. A mixed land use development with residential and commercial functions may only achieve desired vitality if commercial functions are selectively located within the street network. Similarly, neighborhood parks do not contribute to pedestrian activity unless located strategically along critical movement pathways. Hillier describes such locations as integrated network points that facilitate movement through urban space (Hillier, 1996).



Tract A	Tract B
Block Density Index: 36 Intersections Density: 50 Connected Node Percentage: 100% Number of Cul-de-sacs: 0 Number of Street Links: 100	Block Density Index: 8 Intersections Density: 25 Connected Node Percentage: 50% Number of Cul-de-sacs: 25 Number of Street Links: 44
Tract A Connectivity Index = 2.0	**Tract B Connectivity Index = 0.88**

FIGURE. 10 - COMPARISON OF TWO TRACTS WITH DIFFERENT CONNECTIVITY METRICS

Hillier's work catalyzed the development of substantial amount of interdisciplinary research that employed space syntax logarithms in conjunction with various software tools to examine spatial complex configurations and network integration. Space syntax tools are currently utilized in analyzing the impact of land use allocations and movement networks on buildings, blocks, neighborhoods, cities, and metropolitan regions (Salingaros, 1998; Hillier, 1999; Hiller et al., 2010; Jiang and claramunt, 2002; Bafna, 2003; Raford and Ragland 2004; Nophaket and Fujii, 2004; Peponis et al., 2007; Baran et al., 2008).

The syntax analysis generally starts with axial representations of street segments and visibility lines creating a series of intersecting lines and nodes. Each line on the street syntax map represents a pathway and the intersection of two lines corresponds to a network node. The lines on the map with the highest number of nodes and the shortest path between network nodes hold higher connectivity values. The axial representation in and of itself is not the main objective of Space syntax. It only aids in quantifying the topological distance between spaces of a given network. "Depth," "Integration," and "Isovist" are topological measures used in conjunction with space syntax analyses (Xie, 2013, Batty and Rana, 2002; Jiang and Claramunt, 2002; Jeong and Yong, 2020). Depth refers to the number of intervening streets or links leading from one space to another across the movement network. Depth has two values: "local" and "global." the local depth of a given line is acquired by adding the number of lines that bisect it. According to the graph below (Fig. 11), the local depth value of line X is 4. The latter value is equal to line X "connectivity" as defined in space syntax. The global value of line X is determined by calculating three steps of depth: A, B and C. Step A consists of the number of lines that intersect line X multiplied by 1 (depth level 1); step B is the result of multiplying the number of the second group of connected lines in the network by 2 (depth level 2). Step C value is calculated by multiplying the number of links in the third group of connected lines by 3 (depth level 3). The global depth value of line X is equal to 23 (1×4 + 2×5 + 3×3). The higher the depth value and longer the paths of a network, the more segregated or less navigable from one space to another. Integration works in the opposite direction; the shortest and least number of steps between spaces point to a finer grain and more integrated spaces in the urban tract. Integration of a given link or street is obtained by calculating the inverse of the total distance of the shortest lines or street segments from the link or street to other lines in the network. The equation below computes the integration for a given link in a street network (Jiang and Claramunt, 2002; Batty and Rana, 2002).

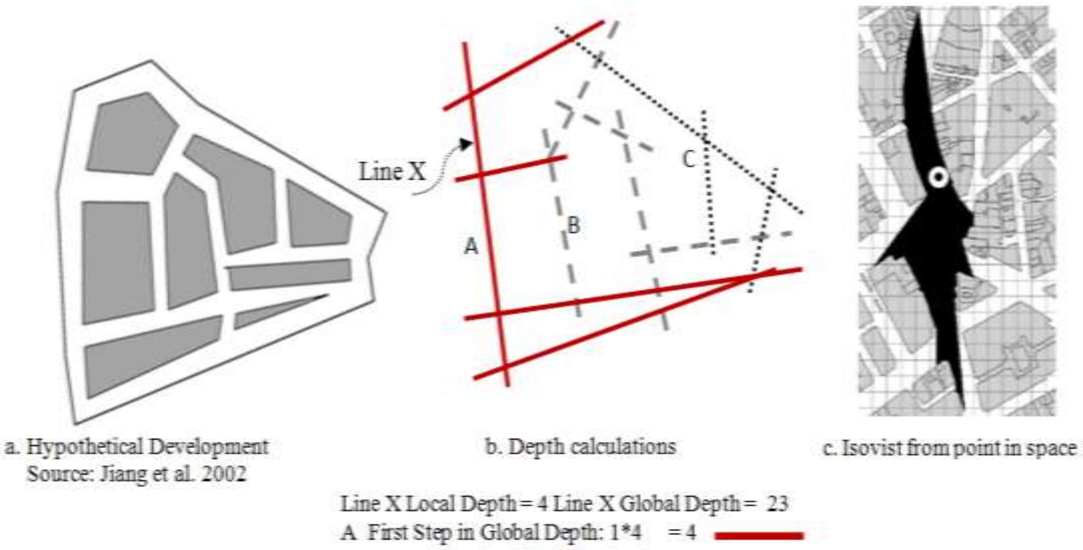


FIGURE 11 - NETWORK SYNTAX FOR A HYPOTHETICAL DEVELOPMENT
(Sources: Jiang et al. 2002, Batty et al. 2002)

The syntax map provides a graphic interpretation of the different integration values of axial lines or streets. The most integrated streets are often depicted with thicker or heavier lines denoting their importance in the network and potential of performing as catalysts for economic exchange activities and urban vitality. They represent the physical and visual skeleton of the city and are often the most familiar and highest navigable elements of the urban network. Land use functions that generally benefit from pedestrian movement such as retail, cafés, parks, or other common facilities ought to be planned along the highly integrated network components. Understanding the symbiosis and/or dialectics between spatial allocations of land use functions and street network configuration is crucial to examine pedestrian activity in cities (Kashef, 2011). Integration can be examined on the scale of a node, street, neighborhood, or city-wide. Within a metropolitan scale, urban areas located at the convergence of major movement paths represent the highest integrated locales in the system. "Choice" is a closely related measure to integration, and it evaluates the shortest path between origin and destination points. Choice measures the sum of shortest paths across a given network from an axis line or space to other elements in the network. Choice is calculated using the following formula (Xia, 2013):

$$\text{Choice} = \sum_j \sum_k \frac{d_{jk}(i)}{d_{jk}}$$

Where d_{jk} refers to the shortest-path between line j and line k; $d_{jk}(i)$ refers to the shortest-path containing line i between line j and line k.

"Isovist" is another key syntax measure that helps to analyze the morphology of public spaces. It examines the range of visibility from critical points in the movement network to determine spatial legibility and its impact on pedestrians behavior. The isovist boundary is changeable based on the vintage point of the observers (Fig. 11c). Lines on the legibility syntax map represent a hierarchy from the longest to the shortest visual axes intersected by critical viewing points, from which maximum visibility fields are determined (Hiller et al., 2010). For macro scale syntax studies, measures such as integration, isovist and depth are all generated automatically using various software tools such as "DepthmapX," "OmniVista," " ArcMap," "AxialGen" and others. The application of space syntax tools to real world context has been criticized on the basis that it relies on two-dimensional mapping and geometric techniques that disregard other critical dimensions of spatial structures (Ratti, 2004). Despite its current limitations, the syntax approach helps in understanding morphological structures and built forms. It tackles movement through space and spatial allocation of public functions and service facilities (Kashef, 2011).

4. DISCUSSIONS

This study investigated the structural considerations of urban vitality, namely mixed-use arrangements, urban grain, and street network physical and spatial parameters. It juxtaposed a broad array of qualitative, design-based theoretical frameworks and quantitative instruments that underline the associations between pedestrian activity and built forms. The bulk of qualitative studies highlighted design aspects and traditional city attributes as foundational for energizing street life. Their call for restoring the traditional spatial and architectural qualities coincide with the cultural shift from modernism to postmodernism with an emphasis on diversity, local context, mixed-use, design aesthetics, and visual dynamics of city spaces (Ellin, 1995; Taylor, 1998; Venturi, 1966; Kashef, 2008). Front and center recommended strategy has been to revive the social, economic, experiential, and symbolic functions of city streets (Krier, 1979; Jacobs, 1961; Duany and Zyberk, 1991; Gratz and Norman, 1998). Over the last three decades, the New Urbanism literature heralded mixed-use built environments with live/work/play configurations and interconnected street networks as critical for enhancing pedestrian activity. The movement associated urban vitality and heightened pedestrian flows in city streets with the proper allocation of uses through space and closely knit built forms. It also highlighted the need for physical elements such as visual stimuli, sidewalks, streetscape aesthetics, bike lanes, and well-designed building/street interface. More recently, the smart growth literature delineated a sustainable development agenda predicated on coordinating land use with mass transit. It called for regional development schemes composed of transit-connected urban centers, subcenters, and various neighborhoods that provide housing, employment, parks, schools, and daily retail services within easy walking distance (Carleton, 2019; Grant, 2009; Sumedha et al., 2005; Calthorpe, 1994; Kelbaugh, 1997).

With a barrage of creative architectural solutions and innovative landscape strategies, the New Urbanism has captured the imagination of practitioners and a segment of the North American population (Hazel et al., 2101). The communal images and entertaining civic possibilities offered by the New Urbanist visions have been realized in some developments that attracted professionals and like-minded people, who place a premium on such aspects as walkability, open spaces, public facilities, etc. (Talen, 1999; Lund, 2002; Morrow et al., 2010).

This study unequivocally recognizes the merits of the rich and extensive planning and design literature associated with the New Urbanism. The latter complements the work of generations of theorists, architects and urban design scholars who have shaped the current understanding of good urban forms (Lynch, 1960, 1981; Jacobs, 1961; Venturi, 1966; Cullen, 1971; Gehl, 1971; Alexander, 1977; Rowe and Koetter, 1978; Rossi, 1982; Barnette, 1995; Bentley, 1985, 1999; Carmona, 2004). The street vitality descriptors set forth in these sources formed the backbone of this study discussions. These included Mixed uses, fine-grain blocks, interconnected and visually stimulating streets and public spaces. Physical elements such as building mass/lines, streetscapes, vistas, porches, ornaments, and the street grid contribute to the livability and vitality of city streets. They have the potential of bolstering the experiential quality of built environments and providing possibilities for social interactions that enrich people’s lives and enhance their sense of place.

Quantitative land use indices confirmed the positive association between balanced mixed-use arrangements and pedestrian movement. The entropy index values closer to “one” have invariably indicated more mix and diversity in land use types, hence, more possibilities for populated street environments (Frank and Pivo, 1994; Manaugh and Kreider, 2013). It was most useful when applied to regulated built environments with distinct land use classifications in neighborhood plots. The entropy statistical modeling did not yield accurate results in cities that permit multiple uses in the same property or have relaxed regulatory systems. Though providing measures of use heterogeneity, the entropy indices sought uniform land use distribution regardless of the level of complementarity between contiguous functions (Hess et al., 2001, Ewing and Cervero, 2010; Gehrke and Clifton, 2016). LUM and Dissimilarity indices, on the other hand, seek to measure land use mix and complementarity in cities that allow multiple uses horizontally and vertically in the same property. LUM computations encompass gross floor areas of uses in built properties rather than functional classifications in building permit registry. In many cities around the world, building uses change through permitted variants or unauthorized modifications. Property owners often adapt their buildings over time to accommodate changing market dynamics and/or residents choices. LUM probably provides more accurate results in such cities, yet it pursues the typical entropy objective of achieving land use mix evenness rather than functional complementarity. Land use calculations may not be confined to urban units independently; the uses of neighboring tracts affect walkability beyond such hypothetical demarcations. The mean entropy index by Kockelman (1997) measures the average of all entropies of contiguous neighborhoods to pinpoint associations between built environment attributes and pedestrian movement. The dissimilarity index complements other entropy measures by computing the dispersion and complementarity of uses in an urban tract. It predicts travel patterns between complementary uses such as residential, commercial, office, and other support functions. However, the dissimilarity index did not account for multiple use configurations in the same property (Hoppenbrouwer, 2005). The quantitative instruments discussed in this study underline the associations between mixed-use configurations and pedestrian flows in city streets and may need to be considered in tandem to arrive at more accurate measures of walkability.

The theoretical investigation of this study revealed variations between design-based approaches and statistical modeling techniques. It is rather evident that both qualitative architectonic and quantitative metrics are vital for an integrative understanding of the built environment features that enhance street vitality. Mixed-use quantitative metrics should be supported by visual and spatial analyses that justify variations in index results from one city to another. Design-based qualitative arguments should also be reinforced by quantitative algorithms that pinpoint specific features and attributes associated with the different modes of pedestrian travel.

5. CONCLUSIONS

The social, economic, cultural, and experiential dynamics of city spaces are intertwined with land use and street network configurations. This study examined a broad array of theoretical frameworks that associate specific built forms with pedestrian travel patterns. It analyzed the impact of mixed-use, urban grain and street network arrangements on pedestrian presence in the public realm. Mixed-use distribution, street network connectivity, and space syntax tools were explained with an eye on their utility in planning and designing active urban streets. By juxtaposing quantitative metrics of land use and street networks with design-based approaches, this study provided an integrative perspective of the built environment attributes that energize street life. Critical discussions of current entropy instruments highlighted the need for more advanced algorithms to accurately measure the mutual dynamics of built environment and walkability. Both entropy and LUM indices predicted pedestrian travel patterns based on even distribution of seven land use categories. Though the dissimilarity index provided a nuanced understanding of the impact of land use complementarity on pedestrian movement, it could not account for heterogeneous functions in the same property. As opposed to these objective instruments, the qualitative narratives emphasized design and precedence as the means of understanding and prescribing the built environment attributes that enhance urban vitality. Design-based analyses generally associated pedestrian movement patterns with the proper allocation of uses through space as well as fine grain spatial structures and built forms. They contextualized mixed uses and street network configurations into a smart growth perspective that calls for reshaping cities into self-sustaining urban neighborhoods with housing, schools, employment, retail, and parks within reasonable walking distance. Both Qualitative and quantitative approaches have demonstrated a level of reliability and validity in predicting pedestrian travel patterns. Despite the overlapping dimensions and agreements between both approaches, this study underlined the need to combine design-based qualitative assessments with quantitative instruments to describe and prescribe the built environment attributes that enhance urban vitality. The analytical discussions of this research potentially generate a robust foundation for future planning and design research aimed at enhancing urban vitality and energizing street life.

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