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# Urban area types and spatial distribution of pedestrians: Lessons from Tel Aviv

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ABSTRACT

This study examines the role of two urban area types – traditional and contemporary – with regard to pedestrian movement volume and distribution. This study focuses on four dimensions of urban areas which have potential influence on pedestrian movement: (i) a spatial dimension based on road network structure; (ii) a functional dimension of land uses such as retail fronts; (iii) a physical dimension of road sections; and (iv) a demographic dimension of population and employment densities. Four research areas in Tel Aviv are examined and each of these areas is divided to two adjacent sub-areas — a traditional sub-area and a contemporary one. The aim is to clarify: (i) the character of urban areas that were created following different urban design paradigms; (ii) the relative contribution of the spatial, functional, physical and demographic dimensions to pedestrian movement in urban areas of different types. The findings show significant differences between adjacent traditional and contemporary sub-areas. Specifically, traditional sub-areas have higher levels of spatial connectivity and retail fronts distribution as well as higher pedestrian movement volume. The spatial dimension has the strongest overall connection to pedestrian movement, and particularly for traditional sub-areas, while the physical dimension has the strongest connection to pedestrian movement for the contemporary sub-areas.



## 1. Introduction

Recently, there has been a growing awareness of the importance of pedestrian movement in the urban realm, while recognizing its environmental, health and safety advantages (Frank et al., 2006; Jacobsen, 2003). This change is occurring after a period of modernist planning which put a big emphasis on making private vehicle movement relatively fast and frictionless (Murrain, 2002). As the connection between urban and transportation planning is becoming clearer (Forsyth & Southworth, 2008) the effects on pedestrian movement call for deeper investigation. A significant body of literature (Hillier, Penn, Hanson, Grajewski, & Xu, 1993; Raford & Ragland, 2006; Read, 1999) has been accumulated with regard to pedestrian movement in traditional environments, though relatively few studies addressed pedestrian movement in contemporary environments.

The general objective of this study is to examine the relationship between two different urban area categories – traditional versus contemporary – and pedestrian movement volume in the city of Tel Aviv. Generally speaking, road network structure can be divided to traditional on the one hand and contemporary on the other according to geometric and configurational attributes such as the number of intersections, number and size of blocks, connectivity and centrality (Forsyth & Southworth, 2008; Marshall & Garrick, 2010; Murrain, 2002; Peponis, Allen, Haynie, Scoppa, & Zhang, 2007). Essentially, areas planned under contemporary planning doctrines combine the functional hierarchy of streets with the neighborhood unit concept, which results in dendritic and disconnected urban networks (Marshall, 2005). In contrast, traditional urban areas enhance accessibility to residential and non-residential land uses through their early-grid network. Furthermore, a study conducted in the US found that areas built after 1950 have a higher average length of street block, a lower number of streets and accordingly are more car oriented with low walkability level compared with areas that were built earlier (Peponis et al., 2007).

Some of the neighborhoods in Tel Aviv are new neighborhoods that were established following a modern planning approach, while other neighborhoods in Tel Aviv are old neighborhoods that were established following traditional urban planning, Hence, due to the varying types of urban neighborhoods in Tel Aviv, we assume that the case of the Tel Aviv is ideal for investigating the implications of different planning approaches on pedestrian movement. Moreover, this study compares adjacent areas, traditional and contemporary neighborhoods, which are similar in socio-economic parameters (see below), yet differ in their urban type.

This study is based on empirical research in four selected areas in the city of Tel Aviv, and aims to clarify: (i) the character of the built environment of urban areas that were created following different urban design paradigms; and (ii) the impact of the built environment characteristics on pedestrian movement distribution in the city's street network. Specifically, pedestrian movement volume in this study reflects an hourly

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average on a typical weekday in the afternoon. Such an investigation may contribute to improving the evaluation of pedestrian movement distribution in urban areas that are already built and those that will be planned and built in the future, as well as to understanding how to create built environments which encourage pedestrian movement. Furthermore, combining physical elements with spatial and functional elements is not common in the related literature and this study aims to extend the understanding on the interplay between these built environment dimensions.

### 1.1. Street network's spatial configuration and pedestrian movement

Many studies dealing with pedestrian movement volume in urban space rely on street network analysis by employing the configurational approach, primarily within the conceptual framework of space syntax (Hillier et al., 1993; Jiang, 2009a; Raford & Ragland, 2006). This theoretical framework is based on a topological-visual analysis of the street network called the axial map, defined as the smallest set of straight axial lines covering the urban street network.

The analysis of the topological relationship between the axial lines produces a number of indices of the street grid (Hillier, 1996a) that describe the centrality of individual axial lines such as: connectivity, integration, and choice. Connectivity denotes the number of directly linked axial lines for a given axial line. Integration indicates the closeness of an axial line to all other axial lines in the system by computing the shortest topological distance of the respective line from every axial line in the road network, while the choice measure reflects the likelihood of through-movement. The integration and choice indices can be calculated on a global level (taking into account the entire axial map), or on a local level according to different distance radii. A higher radius indicates a larger extension of the network. For example, a local integration index with a radius of 3 ($r = 3$) reflects a line topological proximity to its nearby axial lines which includes in the calculation only those lines, which are up to two topological steps away from it. This local index is common in studies that employ space syntax techniques to evaluate pedestrian movement volume (Jiang, 2009a; Raford, 2003; Read, 1999). For a detailed description of the integration and choice indices, which correspond to the graph theory-based measures closeness and betweenness, respectively (see: Hillier & Iida, 2005, pp. 481–483).

In addition to analysis based on axial lines, it is possible to do network analysis on a finer scale through the use of segments. By employing this type of resolution, angular distance (least cumulative angle measure) and metric distance can be considered besides topological distance. Studies comparing the relevance of these three distance measures to urban movement show that angular distance have the highest correlations compared to the other two (Hillier & Iida, 2005; Turner, 2007).

While the space syntax approach relies on a secondary representation of the road network, other analyses are based on the primal representation of the road network map (i.e. using the GIS road center lines map). A study conducted in Hong Kong compared topological analysis based on street names to analysis using space syntax measures. In that study, street name based variables achieved higher statistical correlations to vehicular movement compared to axial based variables (Jiang & Liu, 2009). Thus, street based variables should also be considered in pedestrian movement analyses.

### 1.2. Other factors influencing pedestrian movement

In addition to the influence of the road network on pedestrian movement it was found that the land use layout has an impact on pedestrian distribution in urban space. Several studies found that retail has a strong influence on pedestrians' presence in its vicinity (Liu & Griswold, 2009; Zook, Lu, Glanz, & Zimring, 2012). Other studies combine land use and configurational factors to further understand the relationship between the built environment and pedestrian movement and their respective contribution to an area walkability level (Lerman, Rofè, & Omer, 2014; Ozer & Kubat, 2007; Raford & Ragland, 2006). These studies show that spatial structure tends to have greater connection than retail to pedestrian movement whereas combining them together give better correlation values to pedestrian movement volume. For example, in such combined models for pedestrian movement prediction in Boston, the most significant variable was 'space syntax integration', while other variables that improved the model were proximity to public transit stations and proximity to tourist attractions (Raford & Ragland, 2006).

The physical structure pertaining to the road sections may also have an impact on pedestrian volume. Desyllas and Duxbury (2000) found that sidewalk width correlates with pedestrian movement volume so that excessive congestion of pedestrians on a sidewalk leads to lower pedestrian volume due to slower movement. Another study (Desyllas, Duxbury, Ward, & Smith, 2003) concluded yet again that there is a significant connection between pedestrian volume on a given sidewalk and that sidewalk width.

Lastly, demographic characteristics may also be associated with pedestrian movement volume. Several studies demonstrated correlations between pedestrian movement and population and employment densities (Liu & Griswold, 2009; Kim, Ko, & Lee, 2013), while another study that combined spatial analysis with demographic data showed the demographic attributes had also significant influence accounting for 45% out of the model regression correlation (Raford, 2003).

Based on the scientific knowledge about the distribution of pedestrian movement, the current study focuses on the role of urban character in the relationship between built environment features and pedestrian movement volume in urban space. Four main dimensions of the urban environment which have potential influence on pedestrian movement are considered: (i) a spatial dimension which is based on the road network structure; (ii) a functional dimension of land uses such as retail fronts and public transit stops; (iii) a physical dimension of road sections; and (iv) a demographic dimension of residential and employment densities. The complete list of variables used in this study is specified in Section 2.

### 1.3. Research questions and hypotheses

The research questions are:

1. How are the differences between traditional and contemporary urban areas reflected in terms of spatial, functional, physical and demographic dimensions?
2. How does the different urban character correlate with pedestrian volume movement and distribution at the level of city streets?
3. What is the relative contribution of the spatial, functional, physical and demographic urban dimensions to pedestrian movement? The spatial dimension refers to the spatial relation between urban objects i.e., streets, open spaces and buildings. The functional dimension refers to the functional content of the buildings. The physical dimension refers to the physical dimensions of the urban objects i.e., road width and sidewalk width. The demographic dimension refers to population and employment densities. These are the relevant urban dimensions for pedestrian movement, as discussed in the pedestrian movement research.
4. What are the relationships among these urban dimensions in urban areas of different types?

Following previous studies (Marshall & Garrick, 2010; Peponis et al., 2007) we hypothesize that the differences between traditional and contemporary urban areas would be consistent and substantial, and would lead to a different pattern of walking in them. Based on previous research we also hypothesize that the spatial dimension would have the most significant affect on pedestrian movement compared to the other urban dimensions examined in this research. Furthermore, according to the space syntax theory (Hillier, 1996b, 1999) we assume that the spatial dimension affects land use distribution, especially retail, and would therefore correlate with the functional dimension. Studies on the physical road structure are rarely connected to spatial analysis (Desyllas & Duxbury,