How do network, spatial behavior and land uses shape urban movement?

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Abstract

Movement flows in the city are determined mainly by the to-movement and through-movement potentials of the street network (*network effects*) or to the way people perceive distance (*distance effects*). The aim of this paper is to clarify the respective dominance of each of these types of effects on aggregative movement patterns. The investigation entailed analysis of movement flows obtained through agent-based simulations. The study results show that the use of the through-movement potential depends mainly on the distance effects whereas the to-movement potential depends largely on the network effect. Consideration of land use patterns reduce the distance effects.

Keywords

Cognitive distance, Land use, Space syntax, Urban movement

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Introduction

Previous studies have related aggregate movement flows in urban environments mainly to the street network's movement potentials and to the way people perceive distance as well as choose the shortest routes to their destinations (e.g. Hillier, 2012). These effects are explained as follows: "The objective to-movement and through-movement potentials of the network itself contribute what we might call *network effects* on shaping flows; and these are modified by how human minds contribute *distance effects* through how they read distance in complex spaces" (Hillier, 2012, pp. 23-24). According this view because the way people navigate in space is guided not by metric distance but by topological and angular distances (Hillier and Iida, 2005; Hillier, 2012), the street network's topological-angular movement potentials are used more fully than are its metric movement potentials. Later studies have nonetheless suggested that the underlying street structure determines movement patterns but not the way we navigate in space. That is, urban movement is shaped by network effects and not by agents' spatial behavior (Jiang and Jia, 2011; Omer and Jiang, 2015).The aim of this paper is to clarify what are the relative dominance of the network and distance effects on movement patterns.

Analytical framework

The two cities chosen for the study – Kfar Saba and Beer Sheva – differ in their street patterns, land use distributions and size (Fig. 1), features that enabled us to examine how consistent are the network and distance effects on movement. Data on non-residential land-use buildings were obtained from the *Survey of Israel* as GIS point layers, indicating the location and type of each building within the investigated cities.

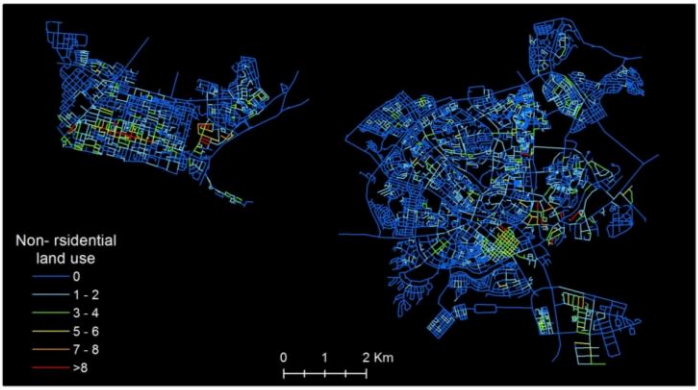

Figure 1 - Street segment maps and land use pattern of the study cities.

To describe the street network structure we used two types of segment-based topological, angular and metric space syntax centrality measures – *Integration* and *Choice* – which correspond to the graph theory-based measures Closeness and Betweenness, respectively (Omer and Jiang, 2015); the first represents the to-movement potential while the second represents the through-movement potential. Construction of segment maps and computing space syntax measures was completed with Depthmp software (version 10.1, UCL). The association between land-use distributions and the segment maps was analyzed by computing the number of non-residential buildings within a buffer of 50 meters in either side of the segment line. The data were analyzed and presented using ArcMap (ver. 10) GIS software.

The agent based simulation model developed was based on two previously published models (Jiang and Jia, 2011; Omer and Jiang, 2015). However, in developing the current model, adaptations were required to enable referencing land-use patterns and street-segment accessibility in selection destinations for movement. Three types of agents were defined – metric, topological and angular – each of whom chooses the shortest path – metric, topological, or angular, respectively. There are two ways to determine origin-destination pairs in the model:

(i) Closeness–based Accessibility: The probability of a street segment being chosen as a destination is directly proportional to its accessibility in the network,

$$\mathrm{Integration}_{Acc}(S_i) = \mathrm{Integration}(S_i) / \sum_{k=1}^{n} Integration(S_k) \quad (1)$$

where n is the total number of streets segments; and S_i is the Integration value of a given street segment (S_i).

(ii) Land use-based Accessibility: The probability of a segment street being chosen as a destination is directly proportional to the number of non-residential buildings located on that segment,

$$\mathrm{LU}_{Acc}(V_i) = 1 + \mathrm{LU}(V_i) / \sum_{k=1}^{n} \mathrm{LU}(V_k) \quad (2)$$

where n is the total number of non-residential buildings in the city; and $\mathrm{LU}(V_i)$ is the number of non-residential buildings in a given street segment.

Results

Table 1 presents the correlations of the Closeness and Betweenness centralities with the simulated aggregate flows of each of the three types of moving agents.

The results show that the Betweenness centrality measure of any given distance type quite accurately reflects agent behavior of the same type. In addition, the Betweenness centrality distributions are quite similar, especially for the topological and angular centralities, which means, significant overlap level between the potential and actual through-movement of different distance types. In contrast, it was found that in both cities, the correlation results reveal a gap between the aggregate flow of moving agents of a specific type and the Closeness centrality.
Moreover, the angular Closeness measure reflects the aggregate flows of all agents better than do the topologic and metric measures.

Table 1 - Pearson correlation coefficients (r) between space-syntax centrality measures (radius N) and the aggregate flows of different agent types. Selection of destinations: Closeness-based accessibility mode. $p < 0.01$ (2-tailed).

		Closeness Measures			Betweenness Measures		
city	Agent	Metric	Angular	Topological	Metric	Angular	Topological
Kfar Saba	Metric	-0.287	0.417	-0.299	0.944	0.621	0.588
	Angular	-0.165	0.517	-0.297	0.532	0.918	0.942
	Topological	-0.191	0.508	-0.309	0.581	0.933	0.977
Beer Sheva	Metric	-0.265	0.492	-0.346	0.950	0.570	0.592
	Angular	-0.130	0.515	-0.289	0.557	0.973	0.734
	Topological	-0.127	0.446	-0.274	0.510	0.702	0.984

When selection of destinations is conducted according to the land use-based accessibility mode, the aggregate flows become more similar and less affected by the distance type used by the moving agents for calculating the shortest routes (Table 2).

Table 2 - Pearson correlation coefficients (r) between space-syntax centrality measures (radius N) and the aggregate flows of different agent types. Selection of destinations: Land-use based accessibility.

		Closeness Measures			Betweenness Measures		
city	Agent	Metric	Angular	Topological	Metric	Angular	Topological
Kfar Saba	Metric	-0.143	0.386	-0.228	0.485	0.626	0.659
	Angular	-0.103	0.396	-0.220	0.346	0.696	0.767
	Topological	-0.112	0.390	-0.221	0.368	0.720	0.804
Beer Sheva	Metric	-0.201	0.350	-0.255	0.517	0.323	0.339
	Angular	-0.155	0.424	-0.266	0.447	0.634	0.541
	Topological	-0.126	0.290	-0.202	0.305	0.320	0.388

That is, not only do actual aggregate flows become quite independent of the to-movement potentials, they also becomes less dependent on the through-movement potentials. This autonomy is nicely expressed in Kfar Saba, where the topological and angular Betweenness measures are much more dominant than is the metric Betweenness measure in expressing the aggregate flows of all agent types, including metric agents.

Conclusion

The study findings lead to two main conclusions. First, the use of the network' to-movement potentials are determined much more by the *network effects* while the use of the through-movement potential is influenced more by the *distance effects* of agents' travel behavior. Second, when movement is conducted in consideration of land-use patterns the aggregate flows of different agent types become similar and quite independent of the distance type (angular, topological, or metric) used by agents for calculating the shortest routes to movement destinations.

References

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