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The extended node-place model at the local scale: Evaluating the integration of land use and transport for Lisbon's subway network

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ABSTRACT

Car dependency and associated car modal share is increasing in the vast majority of metropolitan areas throughout the world, and an important contributory factor lies in the lack of clear and effective integration of land use with transportation. Transit-oriented development (TOD) has been adopted as a major urban policy to achieve such integration. TOD explicitly promotes a balance between public transportation-driven supply and land use-driven demand, while simultaneously improving the pedestrian friendliness of the station areas. The objective of balancing transport with land use is the founding principle of the node-place model. Three principle dimensions can be evaluated under the extended version of this model: i) the node-index, reflecting the accessibility of the station area by several transportation modes; ii) the place-index, reflecting the land use features of the station areas; and iii) the design-index, reflecting the urban design conditions that influence pedestrian accessibility of the station areas. In this paper, we apply the extended node-place model at a local scale, using Lisbon subway stations as the focus points of our analysis, applying the same principles and methodology as for the metropolitan scale, but adjusting the parameters to reflect the subway network. Our results suggest that the introduction of a third index better distinguishes between balanced situations identified in the original node-place model. In Lisbon, the average node index is higher than the place index, and the design index varies substantially across the subway network. In general terms, city center subway stations exhibit the highest index values, whereas peripheral stations tend to be more unbalanced. Transfer stations constitute special cases in the network, having high node and design indexes but average place indexes. The typology of Lisbon subway stations based on the extended node-place model might be used to support urban planning, specifically with regard to establishing regulations for locating activities and parking supply, guiding location-sensitive or place-based fiscal policies, and also identifying the types of intervention needed to achieve the desired integration between transportation accessibility, land use intensity and diversity, and urban design.

1. Introduction

Car dependency and the associated car modal share have been increasing in the vast majority of metropolitan areas worldwide. A significant factor contributing to this phenomenon is the absence of clear and effective integration of land use with transportation. Transit-oriented development (TOD) is a widely used urban policy for fully achieving such integration, taking advantage of the existing transport network and explicitly promoting a balance between transportation-driven supply and land use-driven demand while simultaneously improving pedestrian friendliness, i.e. walkability.

By conceiving TOD as being an urban design archetype, its principles can be applied equally to all station areas of a city or metropolitan area to promote (a certain degree of) density, while simultaneously increasing diversity and facilitating pedestrian-oriented designs around existing and future public transport stations. However, although all station areas are themselves potential TOD locations, not all offer the same multimodal accessibility, so their land use features should be planned accordingly. In other words, although pedestrian-oriented designs can be adopted, the density and diversity of each TOD (i.e., its land use features) should match the multimodal accessibility provided by the station, which is determined by the amount and diversity of transport modes provided by and serving each individual station. Therefore, in order to properly define the framework of a TOD project for any given station area, three different integral aspects need to be considered: (1) multimodal accessibility of the station; (2) land use of the station area; and (3) pedestrian-oriented design so that the station can be accessed and egressed by walking (or cycling). This three-pronged approach has been applied previously in an extension of the node-place model of Bertolini (1999) to include the design aspect of the

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station areas, i.e. the conditions of access to the station (Lyu et al., 2016; Vale, 2015).

Nevertheless, this improvement of Bertolini's original model does not solve one important issue; by focusing on the rail network, several areas of the city are excluded from analysis despite being served by other modes of public transport. Indeed, since the extended node-place model is mainly applied at a metropolitan scale, it is principally focused on regional (suburban) transport modes such as rail (and ferry if present), neglecting 'local station areas' served by other transport modes such as subways or trams. Previous research has applied the original node-place model to other transport modes such as subways, bus rapid transit (BRT), or even simultaneously considering several transport modes, but typically only when the city under study does not have a railway system and without proper consideration of the design features of the station areas (Chorus and Bertolini, 2011; Kamruzzaman et al., 2014; Lyu et al., 2016; Monajem and Nosratian, 2015; Reusser et al., 2008; Vale, 2015; Zemp et al., 2011). In this paper, we apply the extended node-place model at the local scale, focusing on Lisbon's subway system to investigate the applicability of this model at a local scale and also to understand if the TOD types identified by applying the extended node-place model (Vale, 2015) are also present when the focus of the analysis is urban instead of metropolitan. An alternative approach could have been to re-evaluate Lisbon's combined rail, ferry and subway network, which could have provided different outcomes. However, Vale (2015) restricted his analysis to Lisbon's rail and ferry network, allowing him to compare his results with previous applications of the node-place model. Therefore, we feel that by restricting our analysis to Lisbon's subway, we can evaluate classification discrepancies for station areas and our findings can also be applied in other cities where the subway is the main mode of transport and/or the rail network is nonexistent or not very extensive.

2. The extended node-place model

The objective of balancing transport with land use is the founding principle of the original node-place model (Bertolini, 1996, 1999). Three main dimensions can be evaluated under the extension of the original model to include urban design evaluations of the station areas (Lyu et al., 2016; Vale, 2015): i) a node index, reflecting accessibility of the station area by several transportation modes; ii) a place index, reflecting the land use features of the station areas (namely their density and diversity); and iii) a design index, reflecting the urban design conditions of the station areas that influence pedestrian accessibility to the station itself. The original model of Bertolini (1999) is based on a dual axis of node and place indexes, from which five different types of station areas can be identified (see Fig. 1). That original model assumes that a balanced situation reflects a certain degree of mismatch between the node and place values, and identifies three different situations: dependence, balance and stress. By calculating these two indexes, it is also possible to identify station areas that need to increase their place dimension (unbalanced nodes) and station areas that need to increase their node dimension (unbalanced places).

Based on the transportation and land use feedback cycle (Wegener and Fürst, 1999), station areas can be expected to evolve into balanced situations (which still require appropriate land use regulation to promote this equilibrium). However, the feedback cycle is an oversimplification, as the speed of this cycle is not constant. Indeed, some actions are relatively fast (for instance the impact of transport on accessibility), whereas others are much slower (such as the impact of accessibility on land use patterns) (Bertolini, 2017). These different rhythms might explain unbalanced situations between the node and place of a station area, but are also an opportunity to properly guide urban development and transportation supply in order to achieve a desired balanced situation.

The original model was proposed as a methodology for classifying each station area according to these two indexes, thereby identifying its

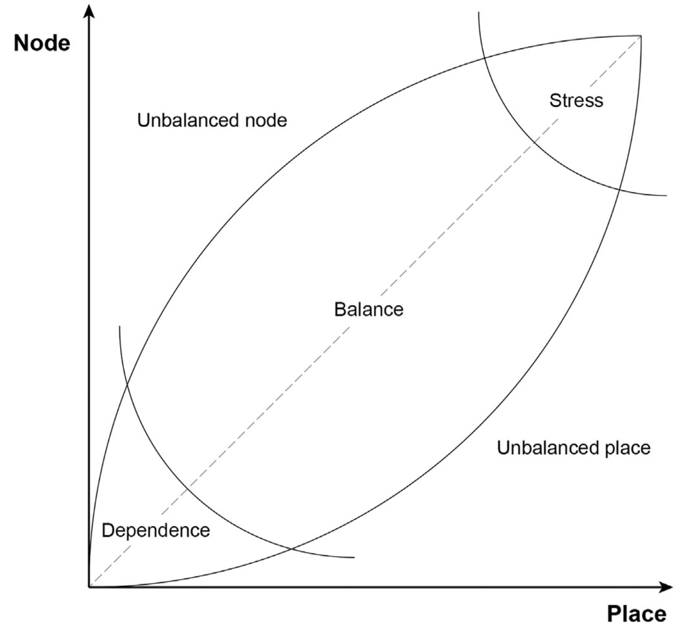

Fig. 1. The node-place model, as defined by Bertolini (1999).

degree of balance and respective typology. Station areas are thus conceived not only as simple nodes in a transportation network, but also as important landmarks in the city where public transport accessibility should be matched by adequate transport density and diversity in order to reduce car dependency. In order to conceive a station as a place, it is necessary to delimit it, which can be achieved by four main approaches: walkable radius, functional-historical, topographic, or development perimeter (Bertolini and Spit, 1998). The walkable radius approach is the most commonly adopted. It is defined by assuming a maximum walking distance (normally 700 or 800 m) or by a maximum walking time (normally 10 min). Therefore, if two stations are located less than 1400 (or 1600) meters apart, the walkable radii of the station areas will overlap, which implicitly infers that the place dimension of the stations have uncertain boundaries. Finally, once the node and place indexes for all station areas of a metropolitan area are calculated, the node-place system of the entire metropolitan area can be determined from the overall mean value, which can be useful for comparing different cities and assessing evolution of a system over time (Vale, 2015).

Note that although the node-place model assumes walking as the egress mode of a station, it is possible to extend the catchment area of each station by considering cycling as the feeder mode. Indeed, improved cycling accessibility can increase use of a train network, and in a much more affordable way than expanding or improving the train service itself (Brons et al., 2009), perhaps justifying station areas being conceived as cycling-accessible areas. Based on this reasoning, Lee et al. (2016) present the concept of a "bicycle-based TOD" (B-TOD), extending the catchment area of the station to ~3 km. They argue that their approach overcomes much of the criticism of TOD, namely its disregard for metropolitan areas that are beyond 10 min walk from a major station. However, to the best of our knowledge, the node-place model has not been applied following the B-TOD concept to date.

Several adaptations have been made to the original node-place model. One major modification is its application to an entire city area instead of only to the station areas. Kamruzzaman et al. (2014) analyzed and classified the entire set of Brisbane's census collection districts, which allowed them to identify what they termed "non-TODs". Likewise, using a 1 km^2 grid, Papa and Bertolini (2015) measured the "TOD degree" of several European cities (Amsterdam, Helsinki, Munich, Naples, Rome and Zurich), expressing the strength of the correlation between a simplified version of the node-index and place-index,

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