Supply side travel zones: An aggregation-disaggregation method for consistent centroid and connector link design

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Extended abstract

Transport models are typically split into two components: A demand model and a supply model. In this paper we focus on road transport, such that the demand model ultimately yields trips, while the supply model describes road infrastructure to load these trips. Demand and supply interaction results in flows and level of service information such as travel times. Rather than using actual departure/arrival locations, trips are mostly modelled from and to travel analysis zones (TAZs). A TAZ is a geographic area adhering to a number of characteristics, which often include homogenous land use, homogeneous population characteristics, boundaries based on topographic, political or census based features, and a relatively constant number of trips across TAZs (Martinez et al., 2009; Baass, 1981). Interestingly, the literature on TAZ design hardly considers the effects of demand and supply interactions, such as, for example, expected road usage. As far as the authors are aware, only simplified proxies such as road types are sometimes considered in TAZ delineation. On the supply side, TAZs are replaced by centroids, a representative point within the original area. Virtual road segments, i.e. connectors, link centroids to the underlying transport network, acting as the interface between demand and supply.

While there exists literature on the placement of centroids (Friedrich and Galster, 2009; Chang et al, 2002; Bovy and Janssen, 1983), the construction of connectors (Jafari et al., 2015; Qian and Zhang, 2012; Benezech, 2011) and the granularity of the transport network (Jafari and Boyles, 2016; Bovy and Janssen, 1983), they assume the underlying TAZs are given and fixed. In this paper we relax the constraint that TAZs are fixed, as we argue that the shape and size of TAZs should consider travel demand and supply interactions. We consider the creation of centroids, connectors and the (aggregate) network in an integrated fashion by proposing novel methodology that: (i) Refines the demand-side statistical areas yielding a TAZ design that considers expected road usage, (ii) constructs centroids/connectors in a novel, yet consistent manner, and (iii) derives the underlying aggregated network automatically. The benefit of considering these issues in unison, is the fact that the transition from demand to supply becomes consistent and reproducible. This in contrast to current practice where, all too often, one relies on ad-hoc decisions by the modeller at hand. To achieve our goal, we require the following inputs: Travel demand, i.e. statistical areas and trip matrices at the highest level of detail available, and the complete disaggregate road infrastructure supply (or the most detailed transport network available).

The framework supporting our proposed methodology is shown in Figure 1. It contains four components described by four implicit functions $f_0(\cdot), \ldots, f_3(\cdot)$. We discuss each component conceptually, leaving the formal discussion for the full paper. TAZs do not simply split or merge geographical areas defined in the travel demand input, but may take entirely different shapes. This flexibility is created by first disaggregating network travel demand across the detailed underlying network as performed by function $f_0(\cdot)$ in order to find the best geographical groupings in consecutive steps. Clearly, if one would have access to individual or household trip data, this first component can be skipped.

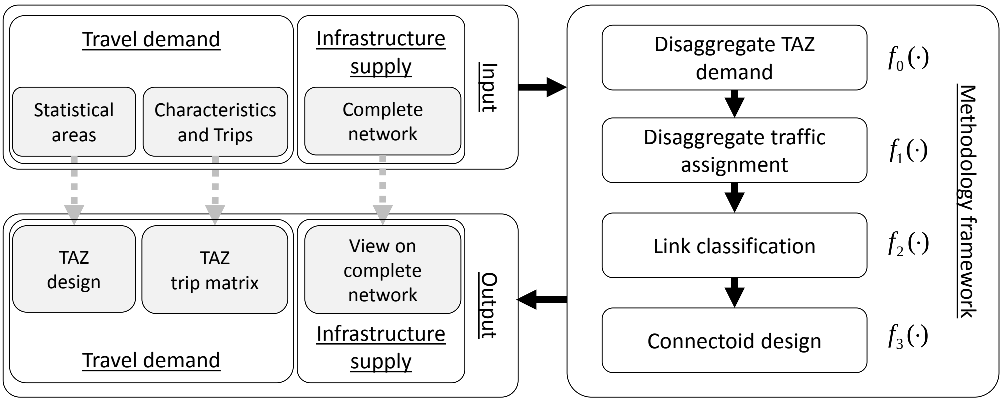

Figure 1: Framework for supply side refinement of TAZs and centroid, connector and network topology design.

Next, function $f_1(\cdot)$ assigns this disaggregated network travel demand using free-flow fastest paths (in the simplest incarnation), resulting in expected road usage information. In order to decide which network elements can be grouped to yield a TAZ, we utilise our expected road usage information to classify links through function $f_2(\cdot)$. To do this, each trip is split into three sections: A *main* section, starting at the first link with an expected road usage above a predefined threshold and ending after the last, and an initial (*departure*) and final (*arrival*) section. Further, each link in the network is classified as either a *departure/arrival* link or a *main* link. Links are classified as departure/arrival when they only contain trips in their departure/arrival section. Otherwise they are classified as a main link. Based on this binary link classification, we derive the (initial) TAZ structure, the centroid/connector interface, as well as the final aggregate "view" on the transport network via $f_3(\cdot)$.

The transport network is modelled as a graph (Figure 2a), with connected components identified via the binary link classification of $f_2(\cdot)$, see Figure 2b. Only connected components of departure/arrival links serve as the foundation for constructing a TAZ [1]. Each TAZ contains one or more *connectoids*, which encompass the boundaries of zones. Each TAZ node that can reach a different connected component through a single link becomes a connectoid (Figure 2b).

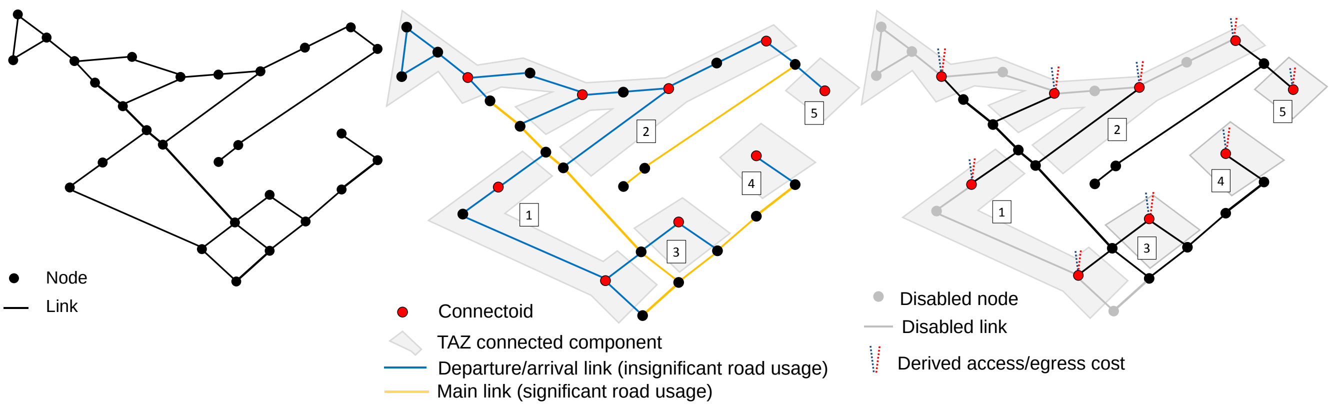

Figure 2: Simplified schematic example of proposed method with, (a) original network, (b) schematic example of the five TAZ connected components based on road usage and connectoid, (c) final network view and impression of imposed cost.

This defines the number of connectoids and ensures a physically meaningful point of departure/arrival, because trips begin/end at a TAZ's connectoid. Connectoids therefore replace the traditional centroid/connector paradigm (which can be considered an alternative representation). Traditionally, connector cost is based on a virtual connector speed, which, combined with its virtual length, yields a travel time cost. Choices regarding connector speed and length are often rather arbitrary. For

[1] Connected components serve as starting point for finding TAZs, details on complete TAZ construction are provided in the full paper.

connectoids, we compute the cost[2] as the average cost to reach the connectoid from all nodes within its TAZ (available via functions $f_0(\cdot)$ and $f_1(\cdot)$).This highlights the benefit of having access to the complete network, even when it is not used in actual assignment. The final network (view) entails disabling all internal links of each TAZ (without necessarily deleting them), Figure 2c.

In the full paper we further discuss the development of the disaggregation-aggregation method which groups and/or splits (initially obtained) TAZs based on desired number of trips, the original statistical areas and user-controlled parameters, which determine to what extent one is allowed to deviate from the original input. A branch-and-bound algorithm is presented as one of the possible ways to solve this optimization problem where we aim to minimise connectoid cost distortion. Because the original statistical areas should be (to at least some extent) taken into account, the constraints are relatively strict, reducing the search space and allowing us to find an optimal solution relatively quickly. Results are presented on a number of case studies on hypothetical and real transport networks to demonstrate feasibility in a practical context.

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[2] This cost is imposed as an additional departure/arrival cost on the connectoid and not on its exit links as they have a physically meaningful cost.