Final Project AC209a

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1 Literature Review

Transportation design and planning methods frequently rely on analytical approximations to quantify distances traveled. For the most general case, the euclidean distance metric is used to estimate point to point trips. This approach is appropriate, for instance, for cases involving national and regional transportation networks. For transportation planning within urban areas, the rectilinear distance metric is generally used. Alternatively, adjustment factors to the euclidean-based calculations have been introduced. Larson and Odoni [1981], using geometric probability principles, proposed a ratio of right angle to the euclidean distance metric to account for the additional distance to the straight line distance estimation, because of the requirements of driving on streets. They estimate this ratio to be close to 1.273.

This ratio-based approach has extended to account for additional elements of real road networks that impact travel directness. Ballou et al. [2002] introduced the concept of *circuity factors* as multipliers to straight line distances to approximate real distances traveled. A circuity factor is estimated as the ratio between the actual and the Euclidean distances. Country-level estimates for this factor have ranged between 1.12 to 2.1 [Ballou et al., 2002]. For travel within metropolitan areas, an average circuity factor of 1.339 has been estimated, based on case studies in the most populated metropolitan areas in the United States. For these same case studies, an average percentage increase of 3.7 percent between 1990 and 2010 has been found [Giacomin and Levinson, 2015].

However, existing results are bounded by two important limitations. First, transferability of the factors found by Giacomin and Levinson [2015] is not guaranteed. Similar to the result found by Ballou et al. [2002] on country level, the circuity factor for metropolitan areas might vary. Louf and Barthelemy [2014] proposed a quantitative method to classify cities in 4 overarching different categories based on their street pattern. Based on the 'fingerprint' of each city, lower level classifications can be made and they conclude that most cities in the USA fall in one category. Applying the circuity factor found by Ballou et al. [2002] might lead to over- or underestimations of the true travel distances indicating the need for a better estimation methodology of the circuity factor. Second, current urban-level factors assume a homogeneous impact to travel directness across a city. This assumption might be viable for passenger travel, (i.e. people going from home to work) but might not be applicable for heavily localized point-to-point urban trips, such courier delivery trips. For instance, a recent parcel delivery case study conducted by the authors in the city of São Paulo, inter-stop euclidean-metric distance ranges on average between 100 meters and 1 kilometer. In those cases, noticeable differences in road infrastructure across city areas should be accounted for to accurately estimate travel distances. Thus, there is a need to capture these factors at the district or neighborhood levels, and explore the drivers of different circuity levels

Previous studies have outlined potential drivers of the circuity factor, including road density, road connectivity or geographic obstacles [Ballou et al., 2002, Giacomin and Levinson, 2015]. However, and particularly for cross-country comparisons, it is unclear to extend to which the quality of the multiple real travel distances sources impacts the results [Ballou et al., 2002]. Moreover, current methodologies rely on very specific datasets, thus limiting ability to replicate the method.

Consequently, our review indicates two gaps in literature. First, transferability of circuity factor is limited, between different geographies as well between different geographical scopes. Second, current methodologies to estimate circuity factors limit the replicability of circuity factor determination and therefore provide limited insights in the drivers of circuity. To the best of our knowledge, none of these gaps have been addressed in the literature so far.

To address this research gap, we will leverage large open data sources and data science methods. Indeed, practitioners in the logistics industry are increasingly relying on different sources of big data to support supply chain decisions. For example, DHL [Jeske et al., 2013] expects a steep increase in using data driven methodologies for supply chain network (re)design. In particular, we will leverage data form Open Street Maps (OSM), the largest open source geographic database that relies on user information. OSM provides its data build up by nodes (a particular point on the map) and ways (a sequence of nodes). Furthermore, road segments are the ways associated to roads and they are further classified into several types, such as motorway, primary road and residential This creates the opportunity to classify cities or city segments based on their infrastructural characteristics and to determine the impact of the identified potential drivers of circuity factor. Moreover, the data provided by databases such as OSM is uniformly available which allows for a methodology that is easily transferable to different urban contexts. Analyses will also be supplemented with travel distance estimations obtained from Google Maps and population data from LandScan.

References

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