Journal of Transport Geography 58 (2017) 196–208

Contents lists available at ScienceDirect

Journal of Transport Geography

journal homepage: www.elsevier.com/locate/jtrangeo

Travel demand corridors: Modelling approach and relevance in the planning process

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ARTICLE INFO

Article history:
Received 13 April 2015
Received in revised form 7 December 2016
Accepted 13 December 2016
Available online 23 December 2016

Keywords:
Demand corridor
Origin and Destination (OD)
Desire lines
Travel demand
Transportation planning
Urban planning
Trajectory clustering
Travel surveys
Travel patterns

ABSTRACT

In an ideal world, transportation networks and services would be adapted to the specific travel needs of each individual and would perfectly fit the corresponding desire lines (direct lines between origin and destination points). However, in practice, networks cannot be designed to accommodate each individual trip. Still, it is possible to optimize transportation systems from a collective demand point of view. To move from an individual to a collective scale, individual demands need to be encapsulated into demand corridors.

Although current spatial tools and data mining techniques are able to identify corridors from numerous movements by using linear or non-linear trajectory data, their limitations—from a transportation point of view—include the use of non-intuitive parameters and the application of some aggregation processes that make it difficult to retrace the attributes of individual input data that could benefit the richness of the available data after processing. For that reason, we propose a new algorithm called Trajectory Clustering for Desire Lines (TraClus-DL), which can identify corridors from Origin-Destination (OD) information with simple parameters, such as spatial location, angles between lines, and sampling weights. The functionality of TraClus-DL as a diagnostic tool for transportation supply was assessed and tested using data from the 2013 OD travel survey conducted in the Montreal area. The sensitivity of the results, with respect to parameter settings, was evaluated, and a comparison with an existing algorithm was proposed.

The results of this study demonstrate that transportation specialists can benefit from the convenience of using TraClus-DL as a corridor identification tool, which includes its potential to perform deep analyses at the corridor level. In addition, this study provides new insights into the possible uses of demand corridors as relevant tools for transportation planning, and in the decision-making processes in which a neutral reference is needed to evaluate how much the transportation supply differs from the collective travel demand.

1. Introduction

In a historical review of urban transportation planning, Weiner (2012) has noted that in the early 1950s network characteristics and travel volume became insufficient for effective transportation planning in complex areas such as urban zones. As a result, data collection methods were developed—for example, Origin-Destination (OD) surveys—and the collected information was analyzed to recognize travel patterns and factors that affected urban movements. By the mid-1950s, >100 OD surveys already had been conducted in American metropolitan areas (Weiner, 2012). Since then, OD data have become valuable resources for providing a clear picture of mobility patterns at both the individual and collective scale, and a great deal of research has been carried out in transportation planning and decision the making processes using the OD survey data. In the past, a lot of research relied solely on aggregated data due to the complexity of data processing with the available tools and the time required; consequently, the methods used did not benefit from the richness of the available data, and the results were limited accordingly. Nevertheless, powerful tools and methods were proposed to handle large sets of micro-data, such as spatial analysis tools (Morency, 2006) and data mining methods (Rao et al., 2011; Guo and Zhu, 2014).

Many researchers have benefited from these advances to better understand mobility and improve their studies using OD data. Some have aimed to improve transportation services (Jara-Díaz et al., 2008) and to assess service accessibility (Jiang et al., 2012), whereas others have used OD data to simply visualize large amounts of disaggregated data (Bahbouh and Morency, 2014).

Any OD survey set carries basic information about individual trips through the origin and destination points. The direct line connecting the origin and destination points represents the theoretical shortest

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http://dx.doi.org/10.1016/j.jtrangeo.2016.12.007
0966-6923/

path for an individual, which is called a *desire line* (Weiner, 2012). Since the transportation supply usually is designed to fulfill collective demand, individual travels need to be synthesized to a collective scale. Methodologically speaking, this means that desire lines need to be aggregated into corridors in which a corridor can be seen as a "watershed" gathering together similar individual trips (Smith, 1999). Therefore, the identification of corridors from desire lines is a way to identify optimal collective axes where desire lines are encapsulated to form what we can call *demand corridors*.

Since most of the research regarding *corridor* definition relies on the presence of physical infrastructures and land use (Chapman et al., 2003; Priemus and Zonneveld, 2003; Reggiani et al., 1995), the optimal mobility axes that reflect collective demand desire may not always be detected.Only a few studies on identifying corridors using the observed demand are included in the literature. For example, Liu et al. (1996) proposed a model to identify rail corridor locations based on pre-defined paths and OD data using an optimization cost approach to adjust corridor locations. Other studies (Clark and Oxley, 1991; Moorthy, 1997) have used an OD matrix and a predefined intra-zonal spider web network to identify corridors. In more recent studies, to minimize costs for both users and operators, Verma et al. (2011) proposed a framework to identify transit corridors based on OD data, road networks, Geographical Information Systems (GIS), and optimization algorithms; whereas Rao et al. (2011) identified urban transportation corridors using aggregated OD data and a data-mining method.

In the available literature, we observed two recurring elements: the use of processed data to simplify the complexity of OD sets, and the use of a pre-identified network and optimization techniques to adjust corridor location. Most of those optimization techniques rely on operational concepts such as optimizing travel distance or travel time.

In a different context, Lee et al. (2007) proposed a framework called Trajectory Clustering (TraClus) to identify animal and hurricane corridors. Bahbouh and Morency (2014) tested the potential of using TraClus to identify corridors from desire lines only, and although they proposed some interesting results, they also highlighted the difficulties inherent in the direct application of TraClus to transportation problems. These difficulties are related to parameter definitions and the mismatch of the TraClus process to desire line features. In fact, TraClus parameters are not easy to select and interpret, since they are formulated using composite distance equations. In addition, the framework does not directly support some of the desire line features, such as direction or sampling weight.

One of the main objectives of the present study is to contribute to the limited existing literature by proposing a well-defined method and practice to define and identify corridors from demand. Furthermore, this study highlights some of the potential benefits of using demand corridors to assess the adequacy of transportation supply with respect to demand.

To identify demand corridors, we propose an improved process of trajectory clustering called Trajectory Clustering for Desire Lines (TraClus-DL), which has been adapted to identify demand corridors from desire lines. The functionality of TraClus-DL as a diagnostic tool for transportation needs was tested using a set of data from the greater Montreal OD survey.

The remainder of this study is organized as follows. Section 2 provides a general corridor classification and a brief definition of some corridor features that were used to design the TraClus-DL algorithm. Section 3 presents the demand corridor identification algorithm (TraClus-DL), and Section 4 demonstrates the functionality of TraClus-DL and the possible implementation of the *demand corridor* concept through two case studies. Section 5 examines the impacts of various parameters, and Sections 6 and 7 discuss the advantages and limitations of using TraClus-DL, and provide a general conclusion.

2. Transportationcorridors

Transportation corridors can be classified mainly into supply corridors and demand corridors. Whereas supply corridors are identified based on transportation supply elements and characteristics such as services, location, and capacity; demand corridors typically are identified based on transportation demand elements, without the direct influence of any administrative or environmental constraints. Supply corridors can be used in long-range transportation planning and the decision-making processes (Carr et al., 2010; Smith, 1999), and demand corridors can be used as a reference comparison unit in decision-making processes to diagnose and evaluate how much the transportation supply differs from the travel demand.

Desire lines are a simple way to represent demand; therefore, directly identifying corridors from desire lines leads to identifying the corridors that most closely match the demand.

A summary of the main corridor features is an essential step in designing an algorithm that can identify corridors from desire lines. We build on the transportation literature (Carr et al., 2010; Smith, 1999; Reiss et al., 2006) that describes corridors as dynamic and linear zones with a high trip concentration. In the following paragraphs, we clarify the main corridor features used in the proposed algorithm.

As a starting point, a minimum number of trips is required to identify the corridor zone that is characterized by a high trip concentration. This *minimum requirement* is highly associated with the study objectives and corridor typology. For example, identifying demand corridors for potential transit services may require more trips than identifying pedestrian demand corridors.

The *dynamic feature* of a corridor refers to the possibility of changing the corridor structure (direction, length, position, etc.) based on mobility variables, such as trip distance, start time, commuter's gender, income, etc. Consequently, it is possible, based on these variables, to identify different corridors from the same data set in the same territory (e.g., rush hour or nighttime corridors, students and professionals' corridors, etc.).

The *linearity feature* is defined by Reiss et al. (2006) as "*the sense of a particular cardinal direction.*" With respect to a demand corridor derived from desire lines, a variable or an equation can be used to measure the similarity of the directions. We propose to use the angle of desire lines to determine if two lines belong to the same corridor or not. Our hypothesis, illustrated in Fig. 1, presumes that two lines with angles differing by 90° or more absolutely belong to different corridors. Corridors act as travel-sheds and tend to gather desire lines from each side of their axes, so the maximum angle between the travel-shed axis and desire lines should not be >22.5°.

Finally, corridors are seen as zones in which similar trips (desire lines) are encapsulated together. These zones are defined by their location, length and width. Thus, a corridor will continue as long as a sufficient number of similar trips are present, and it may be characterized by a minimum length. The width of a zone, called the *influence width*, may vary depending on many factors such as topographical or commuter characteristics. The literature provides various examples linking corridor widths to trip modes; for example, pedestrian or cycling corridors can have widths up to 100 m, transit corridors can have widths up to 2 km, and international trade corridors can have widths in the 10s of kilometers. Furthermore, some studies have proposed assigning an approximate width instead of a fixed one, since corridor width should be able to increase slightly to include nearby similar trips (Reiss et al., 2006; Vermont Agency of Transportation, 2005).

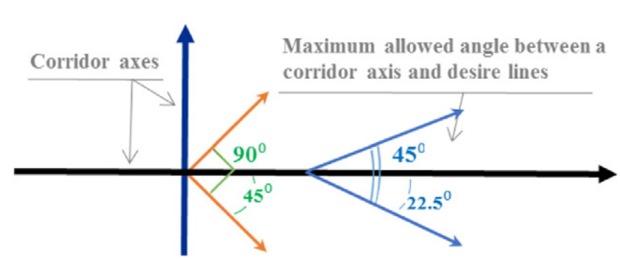

Fig. 1. Maximum angle between the main corridor path and desire lines.