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Measuring the quality and diversity of transit alternatives

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A R T I C L E I N F O

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A B S T R A C T

This research proposes new tools to evaluate transit trips quality and diversity by considering all the transit alternatives to link an origin and a destination. We calculate descriptive indicators for each route, including an improved estimation of waiting time, transfer cost (to measure its tediousness) and consideration of the trip directness. We then filter and rank the results and finally compute two aggregate indicators for each Origin-Destination pair, a Quality Indicator and a Diversity Indicator. For our case study, the Quality Indicator varies between 30% and 70% and captures many local transit features while the Diversity Indicator varies from 1 to 9. Furthermore, by considering the level of similarity between transit alternatives it provides a more accurate representation of actual opportunities than the total number of alternative transit routes. These indicators are excellent diagnostic tools for planners looking to improve transit service.

1. Introduction

Increasing transit's mode share can play a key role in a sustainable mobility strategy. In this context, planners must improve public transit attractiveness for it to compete with private car and increase its market share. But how attractive is transit? Measuring the attractiveness of transit is not a simple task and typical indicators lack the ability to capture various features, such as the directness or the diversity of the available routes. One way to approach the issue is to evaluate every possible transit route between an origin and a destination (O-D). For this paper, transit alternatives are defined as a sequence of transit routes and transfers.

Our general assumption is that it is more relevant to consider all transit alternatives to evaluate transit attractiveness. On one hand, the attractiveness of transit for an O-D pair increases with the quality of each available transit alternative while on the other had, the number of transit alternatives connecting an O-D pair also increases the attractiveness of transit. Thus, the evaluation tools developed in this paper aim to produce two indicators for the whole set of transit alternatives connecting an O-D pair, one measuring quality and another measuring diversity. The idea of considering the whole set of alternatives to assess transit is currently the subject of some research, including the work of Nassir et al. (2016). Their plan to focus on specific O-D pairs and to enumerate all possible paths meets our general research purpose. However, their goal is to measure a level of accessibility on a network using a unique indicator. In our study, the scope is more microscopic through the estimation of two indicators for each O-D pair to directly measure the quality and diversity of the available transit alternatives.

In this paper, we begin by taking a closer look at relevant transportation modeling concepts. We then review the literature on transit quality and diversity measures, and briefly analyze the expectations of travelers regarding public transit. The general methodology and its different steps are then presented. This methodology is then tested using O-D pairs located on the Island of Montreal, our study area. We close the paper with a discussion incuding some research perspectives.

2. Background

2.1. Elements of transportation modeling

Some elements in transportation modeling can provide insights for the evaluation of transit alternatives. Many authors have published reference books that describe the state of the art of transport demand forecasting, like Ortùzar and Willumsen (2011) or Bates (2008). They all consider the typical four-step model, namely trip generation, trip distribution, mode choice and route choice. This last step consists in selecting a path once the origin, the destination and the mode have been chosen for the trip.

There is a variety of research on methods to generate all the possible routes for a trip; Prato (2009) presents some of them. Bovy (2009)note

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that the route choice set should exclude routes with too many common route segments, and aberrations that produce irrelevant routes. Route choice models can also be improved by considering the diversity of alternative routes for a trip. This concept was proposed by Nassir et al. (2014), for whom the presence of many routes linking an origin to a destination creates a higher-value network than one with fewer routes. The authors confirmed their assumption, as they improved the accessibility modeling of the San Francisco bike network. They considered not only the shortest path, but several alternative routes between the origin and destination, and the issue of overlap. Mamun and al. (2013) also calculated an indicator to measure both accessibility and connectivity in a transit network, which can be evaluated at an O-D level. Their so-called “transit opportunity index” includes spatial and temporal coverage of transit routes linking the origin to the destination. Considering a set of transit alternatives rather than only one transit route can also be relevant when route preferences vary across the population. For instance, the model developed by Nazem et al. (2011) shows that the choice of a transit route is highly dependent on demography.

A utility function is typically used to evaluate transit trips. This function assigns a certain value to the time spent during the different phases of the trip, in addition to other attributes, such as monetary costs. For instance, Wardman (2004) showed that in the context of urban bus trips, walking and wait times are valued more than in-vehicle times, 1.79 times more for walking and 1.59 times more for waiting. The perception of time in public transit has also been studied by Anderson (2013). Her research compares the value of time for different trip segments, such as access/egress time, waiting time, transfer and in-vehicle time, scaled to in-vehicle time, for various contexts and in many city's around the world. What's more, an epsilon coefficient is generally added to the utility function to consider all the aspects that fail to be measured.

2.2. Existing transit quality and diversity measures

Many authors have tried to perfect the concept of the utility function to evaluate transit trips by including variables such as the travel mode (Nazem et al., 2011; Anderson, 2013), headway times (Anderson, 2013) or the level of crowding (Raveau et al., 2011). Regarding transit quality of service, Litman (2013) presents different concepts such as reliability, comfort or security. The 3rd edition of the Transit Capacity and Quality of Service Manual (TCQSM) also provides a useful guide to determine the quality of a transit service, considering service frequency, punctuality or passenger load (Kittelson et al., 2013).

Other studies specifically focus on transfer penalties that represent the reluctance of riders to change route during their trip. For example, in studies reviewed in the TCQSM, a value between 12 and 17 min is added to each transfer (Kittelson et al., 2013). Anderson segments transfer penalties per transit mode involved in the transfer (Anderson, 2013). Bovy and Hoogendoorn-Lanser (2005) obtained better results when differentiating between high frequency and low frequency services while accounting for transfers.

Another aspect of transit quality is addressed by Raveau et al. (2011), which is the geometric distortion of a transit route. A cost is thus implemented to evaluate the geometrical directness of a route to link the origin and the destination. This idea is also tackled by Guo (2011) who introduces the concept of distortion between a transit map and the real topology of the network. His model developed with data from the London underground shows that travelers put more value on the distance seen on the map than on the real travel time.

The concept of transit performance may cover various aspects; this is as well discussed by many authors. For example, in their temporal coverage measure, Mamun et al. (2013) include the bus capacity multiplied by the number of runs for each line. At a network level, Mishra et al. (2012) employ the average vehicle capacity multiplied by the number of operations by hour in their formulation of line connectivity. Additionally, Tétreault and El-Geneidy (2010) are interested in the spacing of bus stops as a way to improve the bus performance. Indeed, thanks to AVL and APC data and Origin-Destination survey, they manage to select the best stops on an express bus line in Montreal.

To deal with the issue of overlap between the routes that are generated, some researchers use a special factor. Among them, Cascetta et al. (1996) use the “Commonality Factor” that measures the similarity between routes. Very similar routes will have a larger commonality factor. Ben Akiva & Bierlaire (1999) account for similarity between routes using the “Path Size”. A route showing little overlap with others will have a larger “Path Size” than one with more overlap.

Transit Customer Expectations in Montreal.

To consider what matters to transit users regarding the quality and diversity of their transit alternatives, we analyze some survey results. Several authors specifically focus on the general satisfaction of transit users towards their mode, like de Oña et al. (2016). In their study, they include attributes such as frequency, punctuality, speed of the trip, proximity to the stops or price of the ticket. Guirao et al. (2016) develop an innovative survey to evaluate the importance of transit attributes on a bus line in Madrid. The results show that passengers puvalue a lot punctuality, followed then by frequency and bus driving security.

This type of survey has also been conducted on the Island of Montreal by the Montreal transit authority (STM) in 2014. The survey was conducted with the STM's research panel and depicts customer expectations towards the transit service. The STM operates four subway lines and 220 bus routes; its annual ridership was 413.3 million passengers in 2015. It should be noted that the panel is not perfectly representative of the transit users' population, as some socio-demographic segments are overrepresented, such as elderly people and women. It also includes a larger proportion of regular users than reality. Participants selected their typical transit mode (metro, bus or both) and frequency of use (regular or occasional). Then, they chose their top five expectations regarding transit service among a predetermined set of features. A summary of the results is presented below (Table 1).

As we can see, for both regular and occasional users, a very large majority of users select reliability/punctuality and frequency as their most important expectations. This helps corroborate our assumptions. Indeed, the availability of many high-quality transit alternatives linking an origin and a destination will create a more frequent and resilient transit service, which is very important for transit users.

3. Methodology

The steps of the methodology used to compute the quality and the diversity indicators are presented in Fig. 1, and some of them are detailed below in the text. It is important to note that the specific characteristics of the traveler, such as the gender, the age or the disabilities have not been considered in this methodology. Basing ourselves on a transit trip between two points, we calculated a Quality Indicator and a Diversity Indicator for the set of available transit alternatives. The first step is to define an origin, a destination, and a time slot. Second, a transit trip calculator is used to generate a choice set (alternative transit routes).

Table 1
Top five expectations of users (source: Survey among transit users conducted by the STM in 2014).

Metro customer expectations	Regular N = 1 288	Occasional N = 444	Bus customer expectations	Regular N = 1 015	Occasional N = 344
Reliability	81%	75%	Frequency	85%	79%
Frequency	73%	64%	Punctuality	84%	78%