SETTING A FAIR-FARE STRUCTURE FOR IMPROVED TRANSIT PASSENGERS' ACCESSIBILITY

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Introduction

Accessibility and mobility are two key terms that are widely used in transportation planning. The concept of accessibility has been gaining increasing attention in transportation planning as it reflects the ability to effectively reach opportunities (Handy, 2005). Unlike the concept of mobility, that does not put emphasis on land use (i.e. location of activities and services), accessibility offers transportation planners a holistic and balanced view of the transportation and land use systems (Cervero, 2005). Accessibility usually considers a transportation element and an activity element. The transportation element is influenced by the level-of-service offered by the transportation system, usually expressed by travel time or travel distance (Jourquin et al., 2006). The activity element, on the other hand, is determined by the spatial distribution of the available activities within the land use system (Handy and Niemeier, 1997).

In transit planning, accessibility “to” (i.e. access to transit) and “through” transit (i.e. geographical coverage of transit) are considered as important service quality indicators (Beimborn et al., 2003; Handy and Clifton, 2001; Murray and Wu, 2003). Typically, travel time (or distance) is used as a measure for accessibility “through” transit. In recent studies, researchers pointed out that transit fare could be an obstacle to accessibility. For example, El-Geneidy (2016) suggested that travel cost (i.e. the transit fare one pays) would also influence accessibility through transit. In addition, a more recent study suggested that an increase in transit flat fare would result in a loss in accessibility. Such loss was found to be inversely proportional to the length of the trips (i.e. substantial for short trips and unworthy for long trips), which can be considered “unfair” for short-trip users (Ma et al., 2017).

This study expands on Ma et al. (2017) and constructs a fair-fare structure for improved passengers’ accessibility. It is assumed that a transit agency needs to introduce a new fare policy that will cover its increasing capital and operating costs. A pre-determined loss of accessibility is set for all short, medium, and long trips; and a new fare structure is established accordingly. The City of Kelowna, BC, is selected as a case study.

Literature Review

1. Transit fare changes

A fare policy change is not uncommonly observed, as transit agencies need to cover increasing capital/operating costs and/or decreasing subsides (Fleishman, 1996). The key trends of transit fare policies include: increase in fare levels, simplification of fare structures, elimination of transfers and introduction of day passes, and increase in market-based pricing strategies (Fleishman et al., 1996). Transit agencies may also consider a fare reduction to attract more riders. Numerous research efforts can be found about the influences of transit policy on equity, revenues, and ridership (Ma et al., 2017). The overall goals of transit fare policy include service-related goals, management goals, relational goals, and community goals (Fleishman et al., 1996). However, there is a trade-off between many of the listed goals. For example, achieving management goals by increasing the transit fare would reduce service-related goals. To evaluate numerous fare policies by rating the options, four criteria are usually evaluated: customer, financial, management, and political. Transfer policy is also a crucial factor to consider when developing fares.

2. Transit fare structures

In Singapore, a distance-based fare is utilized on transit buses (Land Transport Authority of Singapore, 2017). Fares are published for different distances (SBS Transit, 2016): for trips shorter than 3.2 km, the base fare is charged; the fare increases for each extra kilometer travelled; a flat fare applies for journeys over 40.2 km. For smartcard users, fares are determined by total distances travelled for each journey, regardless of the number of transfers made; tapping card is required for both boarding and alighting so that the distance travelled can be calculated. For passengers paying cash, fares for each ride are to be paid separately when boarding the bus (i.e. one will only pay up to the transfer point), and a proof of payment will be issued.

In Auckland, New Zealand, a zone-based fare is used for transit buses (Auckland Transport, 2016). The area is divided into 13 fare zones, and fares are calculated based on the number of zones travelled through. Similar to Singapore, for smartcard users the fares are determined according to the overall journey, regardless of the number of transfers made, and tapping card is required for both boarding and alighting so that one's origin and destination are known. For passengers paying cash, fares for each ride are to be paid separately when boarding the bus (i.e. no transfers are allowed).

In Taipei, Taiwan (R.O.C.), a section-based fare is implemented for city bus routes, and fares are charged for each ride individually for both cash and smartcard users (Taipei City Government, 2017). Longer routes are typically divided into 2 sections, where each section is approximately 8.5 km long. For passengers boarding during the first section, payment is collected when they board the bus; for passengers alighting during the second section, payment is collected when they alight the bus. Thus, passengers who crossed dividing point are changed twice the base fare for the ride, while others are charged once only.

Study Context and Data

The selected study area for this research is the City of Kelowna, British Columbia. Kelowna is a medium-sized city in the Okanagan Valley, with population of 121,045 and land area of 211.82 km^2 as of 2014 (Statistics Canada, 2012; Rahman et al., 2016). The public transit system in Kelowna is coordinated by BC Transit. The Kelowna Regional Transit System operates 28 bus routes, with 19 of the routes serving the City of Kelowna. The annual ridership of the Regional Transit System is 4,927,186 (BC Transit, 2016). Kelowna Transit employs a flat fare system of $2.50 for cash fares with unlimited transfers within 90 minutes. Other fare products, such as package of 10 tickets, day pass, and monthly passes are also available.

Accessibility is attributed to both the transportation system and the land use pattern, so both transportation data and land use data is required in this study (Handy and Clifton, 2001). The transportation data includes the transit network shapefile obtained from BC Transit and transit schedule obtained from BC Transit website. The land use data (i.e. the employment data), quantified at Traffic Analysis Zone (TAZ) level, consists of information from census, BC Assessment, Canada Business Points, and enrolment counts from School District 23.

Methodology

In this study, accessibility is measured using the cumulative opportunities method. Cumulative opportunities are the simplest and one of the most widely used methods to measure accessibility, which quantifies the number of opportunities that can be reached within a given time (or distance) threshold from a particular location. The measure of accessibility, A_i, can be represented mathematically as follows:

$$A_i = \sum_{j=1}^{J} a_j \, f(C_{ij}), \qquad (1)$$

$$f(C_{ij}) = \begin{cases} 1 & if\ C_{ij} \leq x_{ij} \\ 0 & if\ C_{ij} > x_{ij} \end{cases} \qquad (2)$$

where A_i is the accessibility of zone i, a_j is the number of jobs in zone j, $f(C_{ij})$ is the impedance function, x_{ij} is the generalized travel time threshold between i and j. The zone is counted if it is reachable within the actual travel time.

The generalized travel time threshold, x_{ij}, is set to be 30, 45 and 60 minutes based on the preliminary analysis that 90% of the transit trips within City of Kelowna are within 30 minutes, while 99% of the them are within 60 minutes. The thresholds of 30, 45 and 60 minutes include the typical components of transit trips: access/egress time, waiting time, on-line travel time, and transfer time. The total travel time, T_{ij}, can be expressed as follows:

$$T_{ij} = t_{ae} + t_w + t_o + t_f, \qquad (3)$$

where t_{ae} represents access/egress time to/from the transit service, t_w is the waiting time, t_o is the on-line travel time, and t_f is the transfer time (if any). Together, the previous components build up the total travel time (T_{ij}) of a transit user (Van Nes and Bovy, 2000).

To calculate the travel impedance, C_{ij}, that consists of both the travel time spent and transit fare paid, transit fares have been converted in terms of time using the following equation:

$$C_{ij} = T_{ij} + \frac{F}{V_t} \qquad (4)$$

where C_{ij} represents the generalized travel impedance from i to j in min, T_{ij} represents the total transit trip travel time in min, F represents the transit fare, and V_t is the value of transit users' travel time in $/min.

The value of transit users' travel time, V_t, is determined from a Multinomial Logit (MNL) mode choice model, which is based on household travel survey data and level of service attributes generated using Google Directions API. Earlier studies have shown that the value of time for transit users in Kelowna, BC is 14.58$/hour (Ma et al., 2017).

A Geographic Information System (GIS)-based model for transit system in Kelowna has been build utilizing the standard version of ESRI ArcGIS 10.1 (Ma et al., 2017). The model is sensitive to one's on-line travel time and transfer time: the on-line travel time includes the vehicle's running time and dwell time based on posted official timetable information, where the coded travel time in the model corresponds to the morning peak period of a typical weekday; the transfer time is estimated as 13 minutes as half the average headway of all transit routes in Kelowna.

Since the developed model was only sensitive to the on-line travel time and transfer time, other travel time components in equation (3) (i.e. waiting time, access/egress time) needed to be discounted from the travel time threshold. To account for the combined access and egress time, a fixed value of 10 minutes was subtracted from the generalized travel time threshold (x_{ij}) assuming 5 minutes' walk to/from bus stops. Waiting time was neglected in this study, since for medium-to-low frequency services passengers tend to match their arriving time at the bus stop to the bus schedule (Vuchic, 2005; Bowman and Turnquist, 1981).

Results

Figure 1 shows the change in accessibility before and after the fare change from \$2.25 to \$2.50, based on the results that Ma et al. (2017) performed. By considering the combined effect of transit travel time and fare, the figure shows different impacts on loss in accessibility for different trips after 11.11% fare increase. For a 30-min generalized travel time threshold, the average loss in accessibility is 8.50%; for 45-min travel time, the average loss is 5.20%; and for 60-min travel time, the average loss is 1.42%. This indicates that the fare change does not affect the accessibility for longer trips, while it does substantially for shorter trips. This result is reasonable since the ratio of transit fare for shorter trips is much higher, when both transit travel time and fare are converted into the same unit.

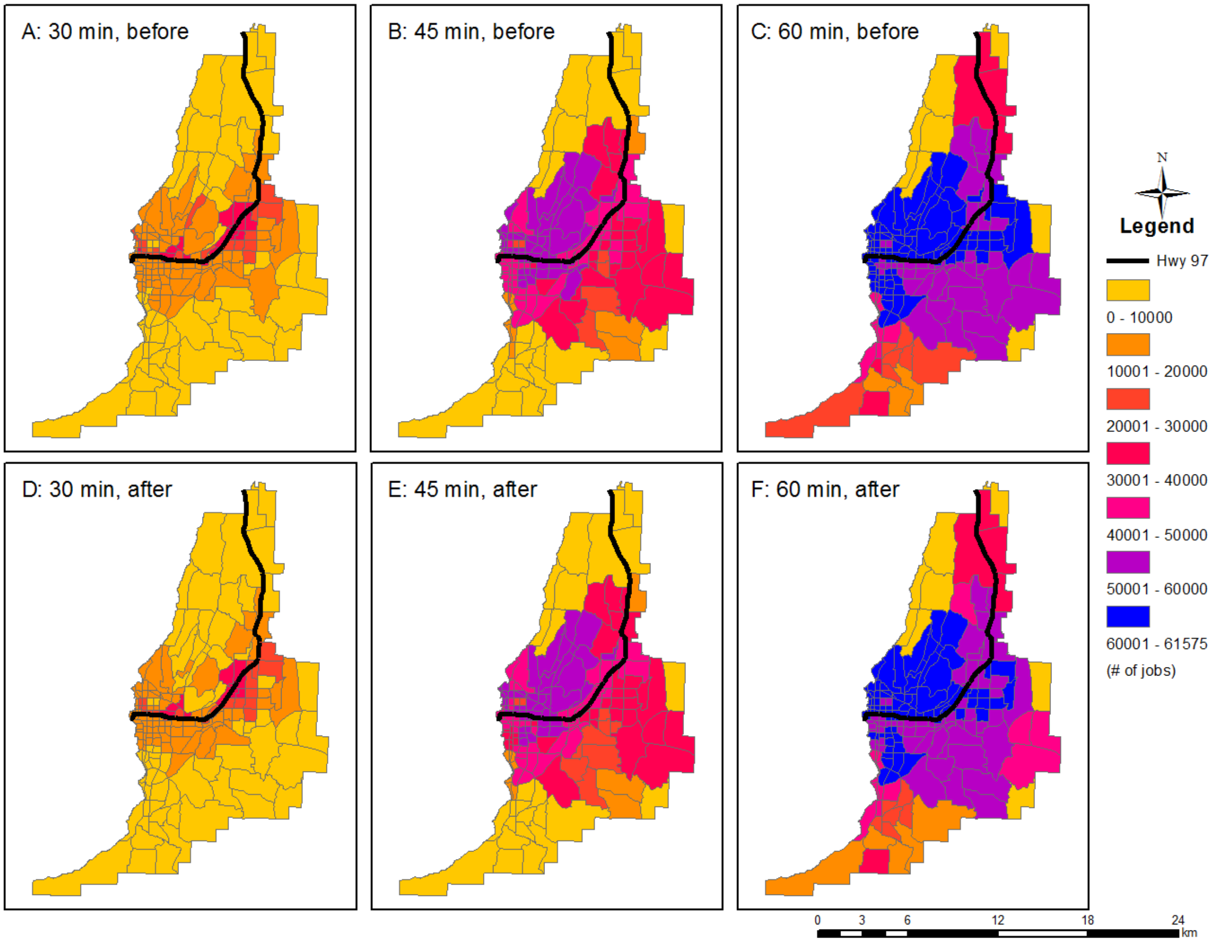

Figure 1. Accessibility before and after fare change (Ma et al., 2017)

As such, a sensitivity analysis was done to ascertain the effects of increase in transit fare on loss of accessibility. Figure 2 demonstrates the loss of accessibility with respect to the changes in transit fare. Figure 2 also shows that due to the increase in transit fare, accessibility of shorter trips (travel time of 30 mins) is severely affected, as opposed to accessibility of longer trips (travel time of 60 mins) which is almost not affected. As such, it should be kept in mind that trips are not affected in the same way in response to a transit fare increase.

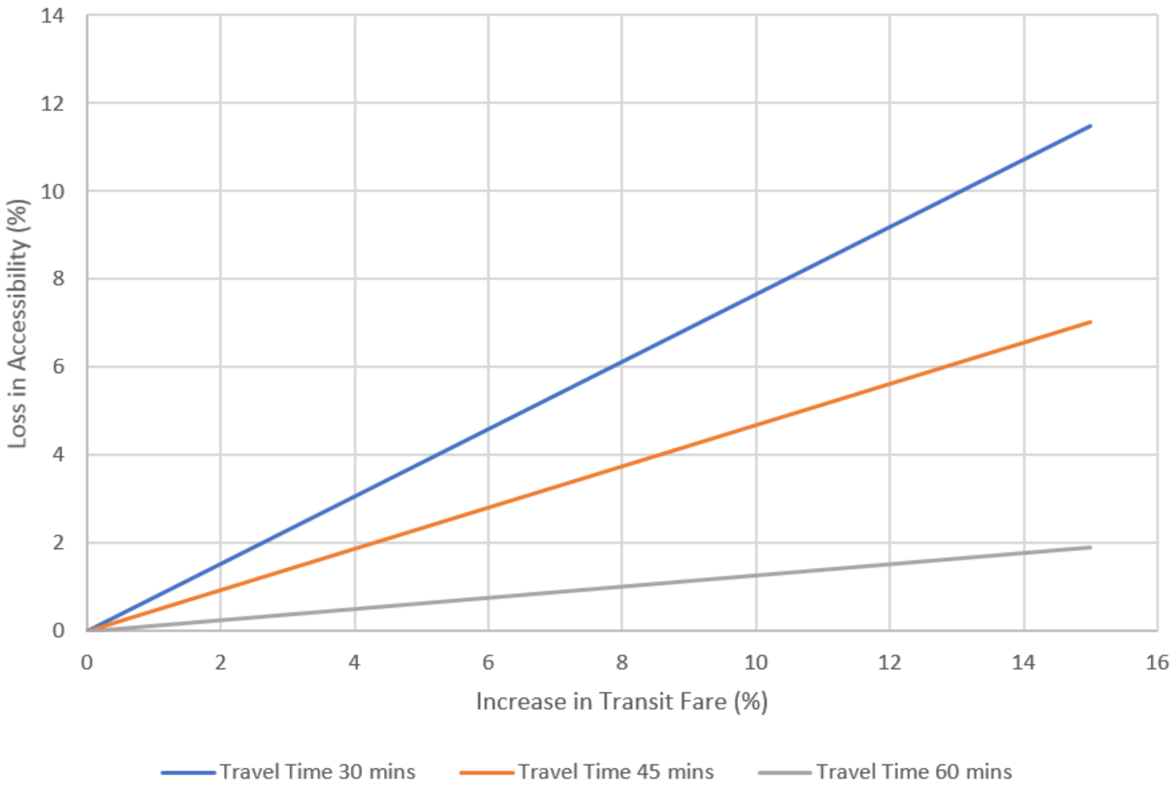

Figure 2. Relationship between increase in transit fare and loss of accessibility

In order to find a fair-fare structure to ensure all short-, medium-, and long-trip passengers lose the same percentage of the accessibility, one could select a value on the vertical axis and draw a horizontal line. The horizontal axis values of the intersection of the curves and the horizontal line would be the percent of increase in the transit fare. For example, if the loss of accessibility is set to be 1%, one could easily determine that the corresponding increase in transit fare to be 1.31%, 2.14%, and 7.82% for short, medium, and long trips respectively (from $2.25).

Conclusion

This paper investigates the different fare structure by fixing accessibility loss in the City of Kelowna, BC. The results show that the increase in transit fare, accessibility of shorter trips (travel time of 30 mins) is severely affected, as opposed to accessibility of longer trips (travel time of 60 mins) which is almost not affected. As such, it is unfair for the one who travelled a short distance to pay the same fare as the one who travelled a longer distance. This paper proposes different fare structure based on the trip length, so that a fair-fare structure can be achieved among passengers based on their trip length. To do this analysis, this paper assumes the accessibility loss regardless of the length of trips. For future study, the implementation plan of the suggested fare structure will be investigated.

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