Modelling the Impact of Transit Fare Change on Passengers’ Accessibility

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ABSTRACT

Accessibility has been one key transit service planning indicator, as it specifies how well a transit system serves the residents. Occasionally, transit agencies may consider a fare change in order to maintain operations or to attract more passengers. However, the effect of such fare change on passengers’ accessibility is not usually considered. This paper investigates the effect of transit fare change on passengers’ accessibility. A Multinomial Logit (MNL) mode choice model is developed to measure the monetary value of transit users’ travel time. Then, the cumulative opportunity measure of accessibility is used to examine the loss in job accessibility after transit fare increase in the City of Kelowna, British Columbia, Canada. The results show that job accessibility is substantially affected by the fare increase for short trips and barely affected for long trips. The findings of this paper should be kept in mind prior to rethinking transit fare structures. For example, one could consider applying a zone-based fare structure as opposed to the flat fare system available to ensure equity for all transit users.

KEYWORDS:
Generalized Travel Impedance, Job Accessibility, Transit Fare Change, Travel Cost, Travel Time, Value of Time
1. INTRODUCTION
Accessibility is a term often used in transportation and urban planning (1, 2). In general, accessibility can be defined as the ability to reach particular destinations where activities are located (3). Accessibility has been traditionally measured by a large variety of indicators. Most measures of accessibility usually combine two elements: a transportation (or impedance or resistance) component and an activity (or attraction or motivation) component (4). The transportation component reflects the difficulty of movement between two nodes in space, determined by the level-of-service provided by the transportation system. The difficulty of movement is usually expressed in different units such as travel distance or time (5). The activity component, on the other hand, reflects the spatial distribution of activities, characterized by both the amount and the location of different types of activities (3). The spatial distribution of activities is also measured in different ways. Of which, the entropy measure has attracted the attention of many researchers (6, 7).

Public transit is an important mode of transportation that provides high capacity, energy efficient, and low emissions movement (8). Accessibility to (and through) transit has been one key transit service planning indicator that reflects the effectiveness of the transit system (9, 10). In the context of transit planning, accessibility is comprised of access (i.e. physical proximity to transit stops/stations) and geographic coverage (11). In accessibility and transit planning terms, the travel impedance of a transit user consists of four components: walking (access and egress) time, waiting time, in-vehicle time, and transfer time (12, 13). This can be represented mathematically as follows:

\[ T_{ij} = t_{ae} + t_w + t_{ij}, \]  

(1)

where \( t_{ae} \) represents access and egress time, \( t_w \) is the waiting time, and \( t_{ij} \) is the in-vehicle time from \( i \) to \( j \). Together, they build up the travel time (\( T_{ij} \)) of a transit user (14).

A lot of research has focused on incorporating accessibility (quantified in terms of travel distance or time) as a determinant of transit service performance. For example, many short-term transit plans have examined what share of transit routes lies within a suitable walking threshold (typically 400 metre or 5 min) from households, jobs, etc. (15).

In a recent study, El-Geneidy, et al. (16) claimed that, beside travel distance or time, transit fare can be a barrier to accessibility, especially for low-income passengers. As such, the authors quantified accessibility in terms of the combined effect of travel time and the out-of-pocket cost of transit (i.e. transit fare converted to time equivalent based on hourly wage) and used this measure to evaluate equity issues spatially. In particular, the authors investigated whether people residing in socially disadvantaged neighborhoods experience the same levels of transit accessibility as those living in other neighborhoods.

It is not uncommon for a transit rider to observe an occasional transit fare change. Often following a specific issue or problem, transit agencies may consider a fare increase in order to maintain operations (17). Fare reduction could also be transit agencies’ choice to attract more passengers and increase their ridership (18).
This paper expands on El-Geneidy et al. (16) to evaluate equity issues temporally (i.e., whether people experience the same levels of transit accessibility after a fare change). In specific, this study investigates the change in passengers’ accessibility after the transit fare change of Kelowna transit, using the cumulative opportunity measure of accessibility. As of September 2015, Kelowna transit delivered an increase in fare levels, increasing the single trip fare from $2.25 to $2.50 ($1 Canadian = 77 cents U.S. in July 2016). Most of the fare products are hiked, while the fare structure and products were maintained. Given that accessibility is sensitive to transit fares, we are interested in quantifying the change in accessibility due to this fare increase. This study provides transit planners and decision-makers with important ideas to consider when revisiting or restructuring transit fares.

2. LITERATURE REVIEW

Accessibility Measures

Historically, the concept of mobility, as an indicator of the ability to get from one place to another, has been the tenet of the mobility-based approach to transportation planning. Recently, the concept of accessibility, as an indicator of the ability to efficiently reach services or destinations, has gained increasing attention as a complement to the traditional mobility-based measures of performance in transportation planning (e.g., levels-of-service, volume-to-capacity ratio, number of trips, kilometres travelled by passengers or vehicles, average delays, etc.) (19). Evaluating performance from an accessibility point of view provides a holistic and balanced approach to transportation planning (15).

Accessibility refers to the ease of reaching opportunities located at different destinations (3, 10). As such, accessibility entails both mobility and proximity. Accessibility can be improved by either increasing the speed of getting between the origin and the destination (mobility), or by bringing the origin and the destination closer together (proximity), or some combination thereof (20). Accordingly, an accessibility-based approach to transportation planning gives legitimacy to alternative land use strategies that reduce traffic congestion and mitigate environmental problems. Notably, the accessibility-based approach to transportation planning gives attention to the compact, mixed-use, and transit-oriented developments that can substitute for physical movement by both shortening travel distances and prompting passengers to walk or cycle instead of driving.

It is clear that accessibility relates to both the transportation system and the land use pattern. Therefore, transportation and land-use data is needed to determine accessibility (10). Various methods exist for measuring accessibility such as the cumulative opportunity, gravity-based, utility-based, constraints-based, composite, and place rank (21). Of which, the cumulative opportunity and gravity-based measures are commonly used in transportation planning.

The cumulative opportunity is the simplest measure of accessibility, which quantifies the number of reachable opportunities (e.g., jobs, shops, etc.) within a given distance or time period threshold from a given location. In the cumulative opportunity method, opportunities are weighted by an impedance (i.e., a decreasing function of travel distance or time for reaching these opportunities). However, an impedance factor needs to be developed, and weights of the destinations need to be determined, which makes the calculation more complex. Alternatively, a binary impedance function (i.e. impedance carrying a value of either one or zero) can be used to reflect whether an opportunity could be reached or not, respectively (4). The drawback of this method is that the
attractiveness and cost of reaching the job is not reflected. The gravity-based measure of accessibility, on the other hand, takes the attractiveness of the opportunities into consideration, but adds more complexity to the calculations. Given that there is a direct relationship between the cumulative opportunity and the gravity-based measures (21), the cumulative opportunity is used in this study for simplicity.

**Value of Time and Mode Choice**

To quantify accessibility, most research accounts only for travel distance or time as the main travel burden (or impedance). However, the burden of travel does not only involve the travel distance (or time) to reach destinations, but also include the out-of-pocket cost of travel. El-Geneidy, et al. (16) tackled this issue in two ways. 1) by converting travel time into monetary value based on minimum hourly wage in Quebec, before calculating the number of jobs accessible within a given monetary value; and 2) by converting transit fare into time based on minimum hourly wage, then calculating the number of jobs accessible within a given time period. In this way, both transit fare and travel time were considered in the analysis. Nevertheless, one could argue that the minimum hourly wage is not a good estimate for the value of time.

The value of time is a key concept in transportation planning that is used to measure the relative importance of time versus cost in travel demand forecasting models and to report on the economic valuation of travel time savings (22-25). Truong and Hensher (26) showed that there exists a relationship between passengers’ mode choice and reallocation of time. Time is a crucial factor when one compares the efficiency of different modes of transportation, and by linking time to the cost of travel, monetary value can be assigned to time (27). As such, a standard method for deriving the value of time is to use the tradeoff ratio implied by the time and cost parameters estimated in mode choice models (28).

Mode choice models are heavily used in transportation planning to understand passengers’ preferences and predict their choices (i.e. the probability of selecting a mode of travel) following a policy change (29). Mode choice models are developed based on the fundamental Random Utility Maximization (RUM) Theory, which assumes that trip makers are perfectly aware of all the information related to their trips; thus, will select the mode of travel that maximizes their utilities (Meyer and Miller 2001). According to the RUM Theory, a utility function (measure of satisfaction) can be represented as:

\[ U_{im} = V_{im} + \varepsilon_{im}, \]  

(2)

where:

- \( U_{im} \): Utility that individual (i) obtains from mode (m)
- \( V_{im} \): Systematic component of utility
- \( \varepsilon_{im} \): Error term or random utility

The utility function consists of two main parts: a deterministic (or systematic) component and a random component. The deterministic component is function of 1) individual characteristics, 2) level-of-service attributes of alternatives, and 3) the interaction between both of them. This can be represented mathematically as:

\[ V_{im} = V(S_i) + V(X_m) + V(S_i, X_m), \]  

(3)
where:

\[ V_{im} \] : Systematic component of utility

\[ V(S_i) \] : Individual characteristics

\[ V(X_m) \] : Level-of-service attributes of alternatives

\[ V(S_i, X_m) \] : Interaction between individual characteristics and level-of-service attributes of alternatives

The random component (or error term) is included in the utility function to account for unmeasured portion of the utility, which can be caused by various factors such as measurement errors (30). For the Multinomial Logit (MNL) model, the random component of utility is assumed to be Independently and Identically Distributed (IID) Extreme Value Type I (31-33); thus the probability of mode selection can be written as:

\[ P_{im} = \frac{e^{U_{im}}}{\sum_{m \in C_i} e^{U_{im}}}, \]  

where:

\[ P_{im} : \text{Probability of individual (i) selecting mode (m)} \]

\[ U_{im} : \text{Utility of individual (i) for mode (m)} \]

\[ C_i : \text{Set of alternative modes available for individual (i)} \]

In this study, a Multinomial Logit (MNL) mode choice model is utilized to estimate the value of time of transit users in Kelowna, BC.

Transit Fare Change

From time to time, transit agencies consider fare increase to cope with the increasing operating cost and/or decreasing subsidies often carried out following a specific issue or problem (17). Key trends and developments to deliver fare change include: (1) increase of fare levels; (2) change in fare structures; (3) elimination of transfers and introduction of day passes; and (4) increase in market-based pricing strategies. Since 2015, numerous transit agencies in Canada have raised their transit fares. Among them, Calgary Transit increased their single-trip fare from $3.00 to $3.15 (5\% increase) as of January 2015 (34). The Toronto Transit Commission (TTC) has increased their single trip fare from $3.00 to $3.25 (8.33\% increase) in January 2016 (35). The OC Transpo in Ottawa, ON rose their single trip fare for regular routes from $3.45 to $3.65 (5.80\% increase) in July 2016 (36). Other agencies, on the other hand, maintained single-trip fares yet increased monthly pass fares (37), or eliminated free transfers (38).

While fare increase could be an option for transit agencies to deal with their tight budgets, fare reduction could help transit agencies promote their ridership. Sharaby and Shiffan (18) showed that fare reduction is significant for attracting transit users. (39) compared the impacts of different fare increase options on equity and potential fare revenues for Alameda–Contra Costa (AC) Transit, where a similar fare system as Kelowna Transit exists. Both systems employ a flat fare including a free transfer in Kelowna, while a transfer can be purchased with a small fee in AC. In addition, monthly passes and packages of 10 tickets are available in both systems. The results indicated that, between option 1) decreasing single fare but eliminating transfers, monthly passes and prepaid tickets and option 2) maintaining fare structure but increasing fare levels; the latter
options was more favourable. While research has shown that accessibility is sensitive to transit fares, few researchers have investigated the effect of fare change on accessibility.

3. STUDY CONTEXT AND DATA
The selected area for this analysis is the City of Kelowna, located in the Okanagan Valley, south of British Columbia, Canada. Kelowna is a small city yet the largest city in the Okanagan Valley with land area of 211.82 km² and population of 117,312 people (40).

Data used in this investigation comes from various sources. Employment data was quantified at the Traffic Analysis Zone (TAZ)’s level by combining information from census, BC Assessment, Canada Business Points, and enrolment counts from Central Okanagan School District (SD23), among other sources. As of 2014, the total number of employment in Kelowna is 64,095, with 12,608 retail jobs, 2,124 agriculture jobs, 7,862 institutional jobs, and 9,638 manufacturing and construction jobs, 31,848 service and office jobs, 1,726 school jobs, and 312 transportation and utility jobs. The employment density of the study area is shown in Figure 1. It can be seen that most of the jobs are concentrated along the Highway 97 corridor.

![Figure 1. Employment Density of the City of Kelowna](image)

The transit service in Kelowna is coordinated by BC Transit, one of the agencies that coordinate transit service delivery in the Province of British Columbia. Transit network, stop locations, and service timetables as of April 2016 were obtained from BC Transit website. Kelowna Regional Transit System operates 28 bus routes, with 19 routes serving the City of Kelowna, in addition to
Vernon transit route 90 that connects Vernon and Kelowna. The annual ridership of the system is 4,848,971 (41). Kelowna Transit employs a flat fare system with four types of fares available for adult passengers: cash fare, package of 10 tickets, day pass, and monthly pass. A paper transfer that allows passengers to travel up to 90 min on any transit route in any direction, including the Vernon transit routes, can be issued as passengers pay the fare. A magnetic fare card system is used for monthly passes. Students and seniors may qualify for discounts on package of 10 tickets and monthly passes. The transit network with a total of 184 Traffic Analysis Zone (TAZ) boundaries and centroids is shown in Figure 2.

As of September 2015, a fare change has been introduced to the Kelowna Regional Transit System, where most of the passengers are affected. Cash fare was increased from $2.25 to $2.50, package of 10 tickets was increased from $20.25 to $22.25, day passes were increased from $6.00 to $6.50, and monthly passes were increased from $60.00 to $70.00 (42). We are interested in how much accessibility is lost in response to this fare change. In this study, the adult cash fare before and after the fare increase is used.

Information on mode choice, trip length, duration, purpose, etc. was obtained from the 2013 Okanagan Travel Survey, the most recent household-based trip diary survey that was conducted in fall 2013 and covered a sample of residents of the Central Okanagan and the City of Vernon. The survey yielded 22,500 trip records with information at the household, personal, and trip levels. The sample was cleaned to exclude data points with missing information and then filtered to include only work trips with both trip ends located in Kelowna. Work trips are defined as trips from home to work/school or vice versa. The final sample size was 3,638 work trips, with the characteristics of the sample as shown in Table 1.
<table>
<thead>
<tr>
<th>Variable</th>
<th>Category</th>
<th>No. of Observations</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Age</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(05-14)</td>
<td>482</td>
<td>13.2</td>
<td></td>
</tr>
<tr>
<td>(15-24)</td>
<td>630</td>
<td>17.3</td>
<td></td>
</tr>
<tr>
<td>(25-34)</td>
<td>668</td>
<td>18.4</td>
<td></td>
</tr>
<tr>
<td>(35-44)</td>
<td>606</td>
<td>16.7</td>
<td></td>
</tr>
<tr>
<td>(45-54)</td>
<td>678</td>
<td>18.6</td>
<td></td>
</tr>
<tr>
<td>(55-64)</td>
<td>509</td>
<td>14.0</td>
<td></td>
</tr>
<tr>
<td>65 and over</td>
<td>65</td>
<td>1.8</td>
<td></td>
</tr>
<tr>
<td><strong>Gender</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>1,752</td>
<td>48.2</td>
<td></td>
</tr>
<tr>
<td>Female</td>
<td>1,886</td>
<td>51.8</td>
<td></td>
</tr>
<tr>
<td><strong>Availability of driving license</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>2,930</td>
<td>80.5</td>
<td></td>
</tr>
<tr>
<td>No</td>
<td>708</td>
<td>19.5</td>
<td></td>
</tr>
<tr>
<td><strong>Number of household vehicles</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0</td>
<td>100</td>
<td>2.7</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>1,008</td>
<td>27.7</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>1,566</td>
<td>43.0</td>
<td></td>
</tr>
<tr>
<td>3+</td>
<td>964</td>
<td>26.5</td>
<td></td>
</tr>
<tr>
<td><strong>Job status</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Works full-time</td>
<td>2,124</td>
<td>58.4</td>
<td></td>
</tr>
<tr>
<td>Works part-time</td>
<td>533</td>
<td>14.7</td>
<td></td>
</tr>
<tr>
<td>School full-time</td>
<td>993</td>
<td>27.3</td>
<td></td>
</tr>
<tr>
<td>School part-time</td>
<td>81</td>
<td>2.2</td>
<td></td>
</tr>
<tr>
<td>Not working</td>
<td>48</td>
<td>1.3</td>
<td></td>
</tr>
<tr>
<td>Retired</td>
<td>38</td>
<td>1.2</td>
<td></td>
</tr>
</tbody>
</table>

In addition to the previous dataset, level-of-service attributes (i.e. travel time and travel distance) were generated for each trip using each mode of travel, regardless of the actual chosen mode. Level-of-service attributes were generated for car, transit, walk, and cycle using the Google Directions API given respondents’ residential and work postal codes (43). For transit trips, Google Maps reports only on access time, in-vehicle time, transfer time (if any), and egress time (i.e. it does not report on waiting time at the initial stop).

The preliminary analysis of transit level-of-service attributes indicated that 90% of Kelowna transit trips took place within 30 min and 99% of Kelowna transit trips took place within 60 min travel. These numbers were used to guide the travel threshold used in this study. In other words, a generalized travel time threshold (i.e. combined transit travel time and time equivalent of transit fare) of 30, 45, and 60 min was used.

4. METHODOLOGY
This study investigates the impact of transit fare increase on job accessibility. As opposed to El-Geneidy, et al. (16), transit fare was converted into time based on transit users’ value of time,
computed from a Multinomial Logit (MNL) mode choice model. The developed mode choice model utilized household travel survey data and level-of-service attributes generated using Google Directions API. The developed model was then used to estimate transit users’ value of time from the trade-off ratio implied by the travel time and travel cost parameters in the model. Given that Google Maps does not report on waiting time at the initial stop, the estimated value of time is function only of access time, in-vehicle time, transfer time, and egress time.

As mentioned earlier, a generalized travel time threshold (expressed in units of time) of 30, 45, and 60 min was used in this investigation by combining transit travel time and the time equivalent of transit fare (i.e. fare converted into time). This can be represented mathematically as follows:

\[
C_{ij} = T_{ij} + \frac{F}{V_t}
\]  

(5)

where \(C_{ij}\) represents the generalized travel time threshold from i to j in min, \(T_{ij}\) represents the transit travel time in min, \(F\) represents the transit fare ($2.25 before the increase and $2.50 after the increase), and \(V_t\) is the value of transit users’ travel time in $/min.

To carry out the analysis, a Geographic Information Systems (GIS)-based network model was built for Kelowna Transit using a standard version of ESRI ArcGIS 10.1. The travel time on each transit segment was calculated for each route based on the official service schedule information of a typical weekday and nearest bus departure to 7:00 am. The calculated segment travel times include two components: running time (i.e. time spent travelling between stops) and dwell time (i.e. time spent stopped at stops to allow passengers to board and alight) (8, 13). Segment travel times were then manually coded into the Kelowna transit network shapefile.

From a passenger’s viewpoint, the calculated segment travel time is equivalent only to the in-vehicle travel time on that segment. i.e., the developed network model was only sensitive to the in-vehicle travel time. As such, access, waiting, transfer, and egress times as well as the time equivalent of transit fare were discounted from the 30, 45, and 60 min generalized travel time thresholds to end up with the in-vehicle time. For this task, a 400 metre (5 minutes) walk to and from bus stops was assumed. Accordingly, a fixed value of 10 minutes was subtracted from the generalized travel time thresholds to account for the combined access and egress times. Waiting time was neglected in the analysis, as passengers tend to minimize their waiting times by managing their arrival time at the bus stop to match the bus schedule (44). Transfer time was also neglected, as it can be minimized through synchronized timetables (45). Finally, the time equivalent of transit fare, as calculated form the mode choice model, was also removed from the generalized travel time thresholds to end up with the in-vehicle time (\(t_{ij}\)). By utilizing the Service Area function in ArcGIS Network Analyst and the resulting in-vehicle time (\(t_{ij}\)), a service area was established from the centroid of each TAZ, where the centroid of each TAZ is assumed as the origins for all trips from that TAZ. All 184 TAZs in Kelowna were considered in this analysis.

Next, the number of jobs reachable within 30, 45 and 60 min generalized travel time thresholds (after discounting different transit travel time components) was calculated using the cumulative opportunity measure of accessibility (\(A_i\), as follows:

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

(6)
\[ f(C_{ij}) = \begin{cases} 1 & \text{if } C_{ij} \leq x_{ij} \\ 0 & \text{if } C_{ij} > x_{ij} \end{cases} \]

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

The corresponding coverage area for each TAZ was extracted in separate files. The land use shapefile was then clipped with the split files one-by-one to include the number of opportunities covered. The resulting files were then clipped with the actual coverage of bus stops, based on 400 m walk to get a more accurate measure. The total number of accessible jobs covered was then calculated, to get the cumulative opportunities of each TAZ \( (A_i) \). Two Python codes were written to automate this process.

5. ANALYSIS AND RESULTS

Using data from the household travel survey and generated level-of-service attributes, a simple mode choice model was developed for work trips. The developed model considered three modes: 1) automobile, 2) transit, and 3) active transportation (AT). Table 4 shows the specification of the developed model, with Rho-squared value of 0.638.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Mode</th>
<th>Parameter</th>
<th>t-stat</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alternative Specific Constant</td>
<td>Transit</td>
<td>-1.04</td>
<td>-1.60</td>
</tr>
<tr>
<td></td>
<td>AT</td>
<td>0.557</td>
<td>2.11</td>
</tr>
<tr>
<td>Vehicles/person in the household</td>
<td>Auto</td>
<td>1.20</td>
<td>6.00</td>
</tr>
<tr>
<td></td>
<td>Transit</td>
<td>-0.917</td>
<td>-2.45</td>
</tr>
<tr>
<td>Bikes/person in the household</td>
<td>Auto</td>
<td>-0.503</td>
<td>-2.69</td>
</tr>
<tr>
<td></td>
<td>AT</td>
<td>0.578</td>
<td>2.87</td>
</tr>
<tr>
<td>Age Group 3 (15-24)</td>
<td>Auto</td>
<td>-1.27</td>
<td>-7.05</td>
</tr>
<tr>
<td>Age Group 4 (25-34)</td>
<td>Auto</td>
<td>-0.497</td>
<td>-3.15</td>
</tr>
<tr>
<td>Driver's license</td>
<td>Auto</td>
<td>0.563</td>
<td>2.53</td>
</tr>
<tr>
<td></td>
<td>Transit</td>
<td>-0.940</td>
<td>-3.04</td>
</tr>
<tr>
<td>Monthly transit pass</td>
<td>Auto</td>
<td>-1.19</td>
<td>-4.23</td>
</tr>
<tr>
<td></td>
<td>Transit</td>
<td>3.24</td>
<td>9.84</td>
</tr>
<tr>
<td>Employment status (school full-time)</td>
<td>Auto</td>
<td>2.14</td>
<td>5.88</td>
</tr>
<tr>
<td></td>
<td>AT</td>
<td>1.32</td>
<td>3.40</td>
</tr>
<tr>
<td>Employment status (work full-time)</td>
<td>Transit</td>
<td>-0.671</td>
<td>-2.08</td>
</tr>
<tr>
<td>Household income ($25,000 - $45,000)</td>
<td>Transit</td>
<td>0.687</td>
<td>2.80</td>
</tr>
<tr>
<td>Travel time</td>
<td>Auto</td>
<td>-0.118</td>
<td>-1.58</td>
</tr>
<tr>
<td></td>
<td>Transit</td>
<td>-0.043</td>
<td>-5.10</td>
</tr>
<tr>
<td>Travel distance</td>
<td>AT</td>
<td>-0.934</td>
<td>-15.04</td>
</tr>
<tr>
<td>Travel cost</td>
<td>Transit</td>
<td>-0.177</td>
<td>-1.12</td>
</tr>
</tbody>
</table>

The modelling results show that the number of vehicles per person in a household is positively associated with the auto mode and negatively associated with the transit mode. Similarly, the number of bikes per person in a household has a negative association with using auto mode and a
positive association with AT. In addition, people who are 15 to 34 years old are less likely to use auto mode for work trips. Driver’s license and monthly transit pass holding have opposite effects on auto and transit users. Level-of-service attributes (i.e. travel time, distance, and cost) have negative signs, as one would expect. For auto and transit modes, increase in travel time is associated with less driving. For AT mode, travel distance have a very strong negative correlation with AT. An expected relationship is also observed for transit fare, the more the fare is, the less the transit option is used.

To calculate transit users’ value of time, the trade-off ratio implied by the travel time and travel cost parameters in the mode choice model was utilized as follows:

\[ V_t = \frac{P_t}{P_c} \]  

(4)

where:

- \( V_t \): Transit user’s value of time
- \( P_t \): Transit travel time parameter
- \( P_c \): Transit travel cost parameter

The value of time (\( V_t \)) is calculated to be 0.24 $/minute (14.58 $/hour). This number is close to the minimum wage value in the Province of British Colombia which is estimated at $10.45/hour (46). This finding supports the use of the minimum hourly wage as an estimate for the value of time. Importantly, the calculated value of time does not take into consideration waiting time given that it was not reported by Google Maps. It could be argued that if waiting time was considered, the value of time calculated form the mode choice model would come closer to the minimum hourly wage.

As mentioned earlier, access and egress times as well as the time equivalent of transit fare were discounted from the generalized travel time threshold, while other transit trip travel time components were neglected. So, for the 30 min generalized travel time threshold (\( C_{ij} \)), 10 min was removed to account for access and egress time (\( t_{ae} \)), to end up with 20 min (\( t_{ij} + \frac{F}{V_t} \)). Then, the effect of transit fare (\( \frac{F}{V_t} \)) was removed in order to end up with the in-vehicle time (\( t_{ij} \)). This can be expressed mathematically as follows: 20 - 2.25/0.24= 10.6 min. The same approach was applied to discount the 30, 45, and 60 min generalized travel time thresholds before and after the fare increase.

A service area was established from the centroid of each of the 184 TAZs in Kelowna, where the centroid of each TAZ is assumed as the origins for all trips from that TAZ. Then, the number of jobs reachable within 30, 45 and 60 min generalized travel time thresholds (after discounting different transit travel time components and the time equivalent of transit fare) was calculated using the cumulative opportunity measure of accessibility (\( A_i \)), as described before. Figure 3 shows the analysis results before and after the fare increase.
As shown in Figure 3, a 30-min generalized travel time threshold results in a medium job accessibility in the central area of Kelowna and a low accessibility in the rest of the city. The improved accessibility in the central area of the city is attributed to the 97 express bus route (97X) that runs on the Highway 97 corridor. The 97X serves as a trunk route and provides fast speed and high frequency service between West Kelowna and UBC Okanagan Campus. By adding a 15-min travel time threshold, a high accessibility can be seen in the central area of the city and a medium accessibility can be seen elsewhere. This indicates that people living outside the central area of Kelowna would need to spend 15 extra minutes to access the same number of jobs that the people in central Kelowna do. This finding also reflects the poor transit level-of-service of the feeder routes serving the outskirts of the city. By increasing the travel time threshold by another 15-min, it is observed that other than areas not served by transit, the entire city has high accessibility. In other words, 60 min of generalized travel time can provide access to almost all the jobs in Kelowna (that can be accessed by transit), where both travel time and transit fare are considered.
Further, Figure 4 shows the loss in accessibility after 11.11% fare increase (from $2.25 to $2.50), considering the combined effect of transit travel time and fare.

Figure 4. Loss in Accessibility due to Transit Fare Increase

For a 30-min generalized travel time threshold, the average loss in accessibility is 13.06%; for 45-min travel time, the average loss is 1.16%; and for 60-min travel time, the average loss is 0.02%. 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. This finding could also be attributed to the fact that 90% of Kelowna transit trips are short trips that took place within 30 minutes, as discussed earlier. It is also shown that the central area of the city did not lose much accessibility for medium trips. This is because people who live in this area have access to almost all jobs given the travel time threshold. These findings have to do with the shape of the city, the organization of the transit network, as well as the allocation of the employments (which are concentrated along Highway 97).

The policy implications of the above observations should be kept in mind before rethinking transit fare structures. For instance, to ensure equity, one could argue that passengers who make short transit trips deserve some preferential treatment (e.g. discounted fare, etc.). This could be achieved by applying a zone-based fare structure as opposed to the flat fare system available.

6. DISCUSSION AND CONCLUSIONS

This paper investigated the loss in job accessibility in the City of Kelowna after the transit fare increase that took place in September 2015. A MNL mode choice model was used to calculate the value of time for transit users, which turned out to be 14.58 $/hour. Transit fare was converted to time using this value in order to find the generalized travel time. Then, the cumulative opportunity of each TAZ in Kelowna before and after the fare change was calculated and compared.

The results showed that for short trips, the fare increase negatively affected the accessibility for most of the city area. For medium trips, the central area of Kelowna was not affected while the rest of the city was negatively affected. For long trips, none of the city areas was affected. This finding
can be attributed to the layout of the city, organization of the transit network, as well as the allocation of the jobs. Alternatively, this can be explained by the ratio of travel time and transit fare, when they have the same units. The rapid bus route that operates along the Highway 97 corridor has also contributed to the accessibility of jobs in the city, given the fast speed and high frequency service it provides. The findings of this paper suggest applying a zone-based fare structure as opposed to the flat fare system available to ensure equity for all users.

For future study, more detailed consideration of all travel time components is recommended to improve accuracy. In other words, exact values of access time, waiting time, transfer time, and egress time can be used instead of relying on a fixed value. Further, other methodologies can be used in order to weigh accessibility based on the number of trips made or the attractiveness of jobs. The effect of city layout, transit network, as well as the major corridor on accessibility can also be further investigated.

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