Who, what, when, and where: Revisiting the influences of transit mode share

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ABSTRACT

Public transportation agencies are faced with the difficult task of providing adequate service during peak travel periods while maintaining adequate service for those travelling off-peak or travel outside a city or region's densest areas. The ability or inability of a transit system to meet these needs helps explain transit ridership rates. This research seeks to understand how daily fluctuations in transit service are related to ridership in the Greater Toronto and Hamilton Area (GTHA) for different segments of the labour force. Many variables have been linked to transit use in past research including: frequency and proximity of transit service, socio-economic status, the built environment, and accessibility to employment using transit. However, many previous studies focus only on travel during peak hours. This study investigates if fluctuations in service and demand are related to transit ridership rates. Using six time periods, we produce an improved understanding of daily variation in transit mode share for commuting trips. By further dividing the commuting population into two employment wage categories, we demonstrate that the common understanding of the causes of transit ridership is potentially misleading. Commuting transit mode share and the variables that influence it are intimately related to when travel is needed, and to what jobs people are traveling to. To encourage transit use, agencies and researchers need to take into account commuters' need to commute at a variety of time periods.

INTRODUCTION

Why do people use public transit? Most answers mention socio-economic reasons, ease of use (proximity and frequency of transit), and culture or education. For example, those with a college education are more likely to take suburban commuter trains over other forms of transit (*1*). However, these influences are secondary to a more fundamental question commuters may ask themselves before travelling; “Does transit work for me?”

There has been much research on determining what makes transit work and what does not. Many commuting studies look at transit mode share to all jobs, ignoring the potential effect job category or occupation class may have on transit mode share and accessibility (*2*). Foth et al. (*3*) found that job category does have an effect on transit mode share. However, they used broad categories that included a wide range of wage groups, potentially ignoring the effect wage has on transit ridership. This effect may be present because social deprivation and low income have long been linked to transit ridership (*4*). In addition, income has been linked to captive transit ridership, which is caused when income limits access to other modes (*4*). Yet, there has been little effort to study *when* transit works and *when* it does not. Although a person’s economic situation stays fairly constant throughout the day, the ease of using public transit can fluctuate, sometimes with great volatility.

This study asks if there is a relationship between the transit mode share of two wage groups and daily fluctuations in transit service and job availability. The research setting is the Greater Toronto and Hamilton Area (GTHA), Canada. The answer to this question should be of particular importance to regional transportation authorities similar to Metrolinx (the regional transportation authority of the GTHA), which is tasked with both facilitating cooperation among local transportation operators and developing regional transit service. We incorporate transit service and job availability during different times of the day into statistical models that include spatial and temporal variables known to associate with, if not influence, transit mode share. We hypothesize that the availability of jobs and transit change throughout the day and these changes affect the share of travellers who find public transit convenient enough to use for their commuting needs. Because of these fluctuations, we expect that variable coefficients will vary over the day.

This paper is organized into four sections. The first section briefly introduces the reader to transit mode share research, focusing on what has been reported as typical variables that influence or associate with transit mode share. Next, the data and methodological framework are described, followed by a description of the study context. A presentation of the results follows, where the data is analyzed spatially, temporally, and by job category. Finally, the results are discussed and conclusions identified and summarized.

LITERATURE REVIEW

Variables typically related to transit mode share can be divided into two main groups: those pertaining to the rider’s personal situation (socio-economic and other demographic variables) and those dealing with the activities and connectivity that make up a rider’s milieu (the built environment and transit availability). The following section will discuss these variables, their presence in the literature, and their expected impacts on transit mode share.

Socioeconomic Indicators

The decision to take transit is influenced by a person's social situation and economic standing. A number of variables have been used to capture socio-economic effect. Income is often used as a variable to describe social exclusion, transport disadvantage and equity issues (*4-7*), and lower median income at a neighbourhood scale has been linked to higher transit use (*2; 4; 8; 9*). Higher transit use among those with lower incomes is often described as "captive ridership", a situation where public transit is a person's only affordable travel option (*10; 11*). In turn, captive ridership may lead to lower-income residents moving to areas that are more accessible by transit.(*12-14*).

Yet, social deprivation is not the result of income alone. To more accurately identify deprivation at the neighborhood level, a socioeconomic approach is often used (*15*). Variables usually included are unemployment rate, immigration status, and housing affordability, as well as income. Unemployment is understood to be a suitable indicator of mitigated well-being in the Canadian context (*16*). Similarly, a high concentration of recent immigrants within a neighbourhood may indicate a site of possible social exclusion, or the presence of exclusionary processes or systemic discrimination in housing markets and/or housing policy within a city (*5; 17; 18*). In Canadian urban centers, recent immigrants are more likely to work for lower wages or be unemployed (*19*). Finally, high relative expenditure of individual or household budgets on rent, especially for tenants, could indicate locations where households are struggling to maintain a decent standard of living (*3; 15; 20*). In this paper we apply an index of social deprivation that incorporates income, unemployment rate, immigrant share and housing affordability to identify socially deprived zones at the census tract (CT) level (*3; 21*). Deprivation revealed using this indicator is positively linked to transit mode share in Toronto, Canada (*3*).

The Built Environment and Accessibility

Socio-economic motivations for transit use are just one part of the picture. The built environment, including density, the diversity of land uses, and the urban design of the area (the three 'Ds'), have been shown to influence transit ridership, even when residential self-selection is controlled for (*22; 23*). Residential proximity to transit stops and frequency of service have been shown to associate with higher levels of transit ridership (*3; 5; 24*). In particular, short distances to rapid transit stations, such as subway stops, have some positive effect on transit ridership rates (*25*). In contrast, proximity to controlled access highways has been shown to have a negative influence on transit mode share (*3; 26*).

Accessibility's relationship with transit mode share has also been studied. Accessibility measures account for both the transit service people have as well as the opportunities that are reachable using those services (*27*). Measuring transit accessibility can be as simple as measuring the distance to the nearest stop to more complex measures (for a review see, *28*). However, accessibility measures often make two basic assumptions, which this study avoids. First, there is an assumption that all opportunities attract equally. However, since measures of accessibility aim to take into account opportunities available to the traveler, the type of opportunities the traveler wants to reach should be taken into account (*27; 29*). For employment accessibility, different measures for different job categories may be used as better determinants of mode share for specific working populations. Employment type has been shown to influence travel behavior: managers are more likely to commute from the suburbs, whereas service workers, office workers, and professionals are more likely to reside in the urban core (*30*). Calculating accessibility measures that take into account the jobs labour must reach affords researchers a better understanding of different working-groups' transport needs.

Foth et al. (*3*) divided the Toronto (Canada) labour force into three main job categories, based on National Occupation Classification (NOC), to study transit ridership and equitable access to employment opportunities. However, NOC categories do not fully capture the wide wage differences present within and across them. An inspection of average wages in Toronto by NOC subcategory shows that each major group has within it considerable variation in income (*31*). Since income, and thus wage, has an influence on transit ridership, separating jobs based on wage may be a more appropriate investigative method (*32*).

A second assumption is that accessibility to jobs remains constant over the day or that accessibility during peak travel hours is indicative of a transport system's overall performance. This is clearly not the case when regarding most transit services. Changing schedules and daily network closures (planned or otherwise) affect accessibility in non-trivial ways (*33*). It is easy to imagine that employees who work non-regular or third-shift hours may find using transit impossible or untenable because of a lack of service when they need it.

Recently, a few studies have developed accessibility measures that take into account changing levels of transit service or changing levels of job availability. A first attempt involved generating a single accessibility score, which indicates accessibility at one time period, and combining it with a measure of service frequency (*34; 35*). Lei et al. (*36*) devised a way to incorporate detailed transit schedules into a series of accessibility scores for different times of day. Fan et al. (*37*) followed a similar approach, measuring accessibility on an hourly interval. Owen and Levinson (*38*) developed a continuous measure, where they measured accessibility by the minute, and use these measures to derive the maximum, mean, and minimum. They find that incorporating the maximum and mean in a model offers a better explanation of transit-mode choice than incorporating a single measure of accessibility. These attempts, however, fail to take into account that opportunities (for instance, job start times), not just transit service, also vary throughout the day. One paper, does point this out: Polzin et al. (*28*) offer a good introduction to the nuances of daily variation of transit accessibility, and argue that demand for travel, in addition to transit travel times, also fluctuate throughout the day.

METHODOLOGY

In this section, we describe how we take into account both fluctuations in job availability and transit service to come to a better understanding of transit mode choice throughout the day for two different wage groups in the GTHA. There are three major steps. First, we divide our commuting population into two wage-based groups and calculate their transit mode share. Second, we gather variables pertinent to transit mode share. Third, we calculate accessibility to jobs for both groups. It should be noted that all variables are measured at the census tract (CT) level.

For this study we divided the GTHA into three areas to explore differences in accessibility outcomes across a broad range of settlement typologies. We use the borders of the City of Toronto before it was politically amalgamated with surrounding inner suburban municipalities in 1998 as a base area representing the urban core of the region, including its downtown (*39*). Secondly, we take those areas that are part of the present (post-amalgamated) City of Toronto, excluding the urban core, as the City of Toronto's inner suburbs. The area within the core was often lauded before amalgamation as being a leading example of good public transit planning (*39*). To this day, the main rapid transit services (the subway and the Go-Train) are geared towards serving Toronto's urban core and inner suburbs. To account for the benefit of residing in these locations, two dummy variables indicating if a CT is in either Toronto's urban core or inner suburbs are included. The areas outside of the City of Toronto represent a diverse mix of semi-rural communities and distinct urban areas and cities, including Hamilton, population 0.5 million (*40*), and Mississauga (Canada's sixth largest city), population 0.7 million, (*41*). GO commuter trains and local bus services operate in the region's outer suburban places, and cities like Hamilton and Mississauga envision a transit future that include light rail services of some kind.

To test for the influence that variation in transit service and job availability have on transit mode share, we use a series of Ordinary Least Square regressions, with transit mode share as our dependent variable. First, we divide the working population into two study groups, based on hourly wage. Those jobs with a mean wage of $16.00 dollars an hour or less in the GTHA serve as our 'low-wage' category, while jobs with a mean wage greater than $16.00 dollars an hour in the GTHA serve as our 'higher-wage' category. This threshold is used because it is the living wage for the Toronto region (*42*). Wage data by NOC subcategory is gathered from Statistics Canada's wage report for the Toronto census metropolitan area (*31*). It should be noted that this is average wage in the study area, grouped by NOC subcategory. This means that an individual working in a category with an average wage below $16.00 an hour may be earning more, a caveat that should be remembered. We calculate transit mode share for these two groups to see what relationship typical variables have with each group's mode share. In addition, we calculate transit mode share for all workers in the region (both groups combined) to serve as a comparison category.

Transit mode share for each job group at the CT level is the dependent variable for each model. We use two datasets from Statistics Canada, both of which come from the 2011 National Household Survey to perform this analysis (*43*). The first dataset indicates origins and destinations for all workers at the CT level, organized by six departure times (5am, 6am, 7am, 8am, 9am to noon, and noon to 5am). The amount of trips on different modes, including transit, is reported for those times. The second dataset offers the same information restricted to workers employed in low-wage jobs. The difference between the data for all workers and low-wage workers gives us the same information for higher-wage workers. Collapsing the hours between 9am to noon and noon to 5am is necessary because of Statistics Canada's data suppression rules. A cell that contains less than five actual responses will be suppressed by Statistics Canada. Since departures at these hours are relatively infrequent, a large amount of suppression is to be expected, which would skew any analysis. By collapsing these hours together, data suppression can be lessened. Also note that 40 CTs (out of an original 1330 in our study area) are excluded because National Household Survey data is entirely suppressed for these locations, due to low response rates (*44*). Transit mode share per CT at each time period is calculated as follows: The total number of commuting departures (using transit) at the time period in question, in the wage category in question, is divided by the total number of commuting departures (on any mode) at the same time period in the same wage category. From this data we have 18 transit share variables per census tract (3 wage categories by six time periods).

For all model groups (all jobs, low-wage earners, and the comparison group), one regression is run for each time period, resulting in 18 models (six time periods for three job models), using our 18 transit share variables. All models include the same independent variables, described below. These models help demonstrate that variable coefficients related to transit mode share fluctuate over the course of the day and by job category. A correlation matrix between all continuous variables was produced to determine if there are any multicollinearity problems. No relationship between variables significantly greater than $p>0.6$ was found. Also, some continuous variables demonstrate potentially non-normal distributions, namely "transit frequency", "network distance to highway on-ramp", and "Euclidian mean distance travelled to low-wage jobs." For each of these variables, a natural log transformation was applied, and they were tested. However, sensitivity analysis using transformed variables produced little effect on regression results when compared to the results from models with untransformed variables. Thus, the original untransformed variables are included in our final models. The rest of this section explains the models we use and how variables were calculated. If variables require a specific point origin or destination in order to be calculated, CT centroids are used.

Socio-Economic Index

To test for the effect of socio-economic status, a social index developed in previous research is used. This index is a combination of z-scores of median income, unemployment, share of residents who have immigrated to Canada in the last five years, and share of households who pay rent that is greater than thirty percent of their income at the CT level (for a detailed explanation see, *21*). Data for this measure are taken from the 2011 National Household Survey (*45*), and divided into deciles. CT membership in the 10th decile is considered an indication of being the most socially deprived; in the 1st decile, the least socially deprived. Figure 1 shows the spatial distribution of these deciles in the GTHA, with the borders of the urban core and inner suburbs super-imposed.

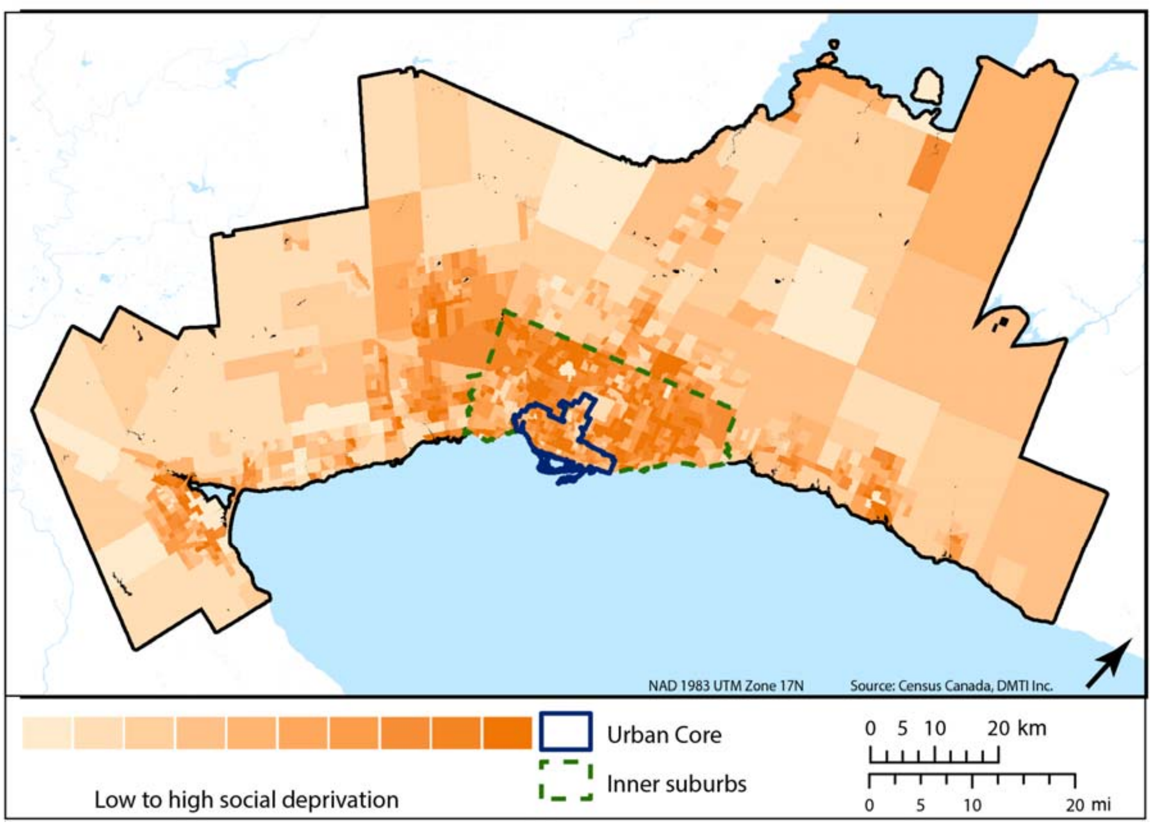

FIGURE 1 Social Deprivation in the GTHA

Built Environment and Transit Proximity

Mean straight-line distance travelled to work from each census tract is included for each wage category. These variables are calculated by determining the straight-line distances of trips (to each job category) originating at a census tract during a day, and weighting these trips by the number of commuters who take each trip (in each job category). This number divided by the total number of commuters (in each job category) at each CT provides the mean distance travelled from each CT during a day. It is generally acceptable to use straight line distances when studying relations at the regional level since the ratio between this distance and network distance is generally stable across a region (*46*).

Two dummy variables, indicating whether or not a CT's centroid is within one kilometer of a subway and whether or not it is within one kilometer of a GO (commuter) train station, are included to test for transit proximity. Distances are gathered using a pedestrian network. One kilometer is used as a buffer because previous research indicates that most people are willing to walk 900 meters but never more than 1750 meters to a rapid transit station (*47*). Distance to the nearest controlled-access highway on-ramp is also measured, using automobile network distances.

A variable indicating transit frequency is included as well. Using General Transit Feed Specification (GTFS) data for the entire GTHA region, a frequency analysis is run using the 'Better Bus Buffers' toolset developed by M. Morang and ESRI (for more information see, *33*). We measure how many transit trips stop within one kilometer of each CT centroid at each hour between 5am and noon, on a typical Monday. The mean of these frequencies (by hour) is used to approximate morning service frequency at each CT.

Table 1 shows summary statistics for the aforementioned independent variables. Three of the continuous variables display potentially skewed distributions ("transit frequency", "network distance to highway on-ramp", and "Euclidian mean distance travelled to low-wage jobs"), where their standard deviations are greater than their means. Potential transformations were tested (discussed above).

TABLE 1 Summary Statistics

(N=1290)	Mean	Median	SD	Min	Max
Transit frequency (trips per hour)	36.09	20.40	44.36	0.00	339.20
Located in city center	0.12	0.00	0.03	0.00	1.00
Located in inner suburbs	0.30	0.00	0.05	0.00	1.00
Network distance to nearest subway station (km)	24.19	18.74	22.73	0.00	83.97
Network distance to nearest GO station (km)	5.29	4.09	5.00	0.36	53.37
Network distance to nearest highway on-ramp (km)	4.02	3.00	4.72	0.02	53.00
Euclidian mean distance travelled to all jobs (km)	10.21	9.53	4.58	1.32	38.62
Euclidian mean distance travelled to low-wage jobs (km)	11.78	6.63	12.15	0.46	35.42
Euclidian mean distance travelled to higher-wage jobs (km)	9.57	8.79	4.45	0.83	35.35

Accessibility and Travel Time

Accessibility is included to account for the varying levels of service each CT enjoys, to our three wage categories. Accessibility to each wage type is calculated using a gravity-based measure (*48*):

$$A_i^{\text{pub}} = \sum_{j=1}^{n} D_{e^{-\beta cij}}$$

Where A_i^{pub} is the accessibility at point *i* to all jobs (in the category in question) at zone *j* using public transit. C_{ij} is the travel cost (measured in time) between census tract *i* and census tract *j*, and β is a negative exponential cost function. This cost function is derived from reported work trips in the 2011 National Household Survey linked to a transit travel time matrix. Travel time from each CT centroid to every other CT centroid at each departure time period is calculated using current GTFS data for all eight public transit agencies serving the GTHA. These calculations provide a travel time matrix for each departure time period, including travel times from each CT to every other CT. These transit times are estimated using the OpenTripPlanner Analyst, provided by Conveyal (*49*), which uses GTFS data to determine which route is the fastest option between two points at a certain departure time, and records the time it would take. For the collapsed time periods (9am to noon and noon to 5am) an average travel time is calculated. However, for the noon to 5am period, travel time at noon is used because of misleadingly long transit times measured during the early morning hours (when most transit systems are closed).

Job availability data during each time period is gathered from the Statistics Canada dataset discussed above (*43*): the number of jobs available at each time period at a CT is the sum of all trips departing during that time period, ending at the CT in question. The gravity approach to accessibility discounts jobs based on how far they are from a trip origin. The underlying assumption is that jobs farther away are less attractive than those closer. We calculate accessibility at each time period to all jobs, to low-wage jobs, and to higher-wage jobs. In the regression models, the accessibility measure included is the one pertinent to the job and time period under question. For instance, in the 6am model for low-wage jobs, the measure included is accessibility to low-wage jobs at 6am.

Summary statistics for our 18 accessibility measures (one measure for each time period for each job category) are not included for brevity, and can be provided upon request. Since we are interested in the direction of effect, not the magnitude, this omission is warranted. Also note that the raw accessibility scores are divided by 10,000 to increase variable resolution. Also note that upon initial testing, we chose to exclude the models for the 5am time period, for two reasons: each model at this time period has an R^2 value less than 0.300. Also, these model's findings may be circumspect because of a high level of data suppression in the 2011 National Household Survey and misleading travel times generation, due to it being so early in the morning.

FINDINGS

The data suggests that, as expected, transit mode share fluctuates over the day depending on which job category is under inspection (see Figure 2). This indicates that daily fluctuations of some set of factors are influencing transit ridership. Low-wage worker transit mode share has different peaks when compared to higher-wage workers (Figure 2). Figures 3 and 4 show transit mode share fluctuations for these two groups spatially. Transit mode share for those working in low-wage jobs grows throughout the day, peaking between noon and 5am. In contrast, transit mode share for higher-wage workers peaks in the early morning (6am). Their share declines at 8am, only to rise again in the afternoon. It is surprising to find that transit mode share is highest outside of usual commuting to work peak hours (7am-9am) for the low-wage group. This may indicate that low-wage workers use transit service later than better-paid workers. It should also be noted that those working in low-wage jobs always have a lower transit mode share than higher-wage earners, at all time periods. This runs counter to findings that hold that those with lower incomes are more likely to use transit than others (*10; 11*). This lower transit ridership rate may indicate that commuting transit services are not adequately meeting low-wage worker needs.

The regression findings indicate that the relationship variables have with transit mode share fluctuates throughout the day, possibly explaining why fluctuations in transit mode share, seen in Figure 2, occur (Table 2). The changing effect of these variables highlights where fluctuating levels of service and travel need impact transit ridership for our wage groups.

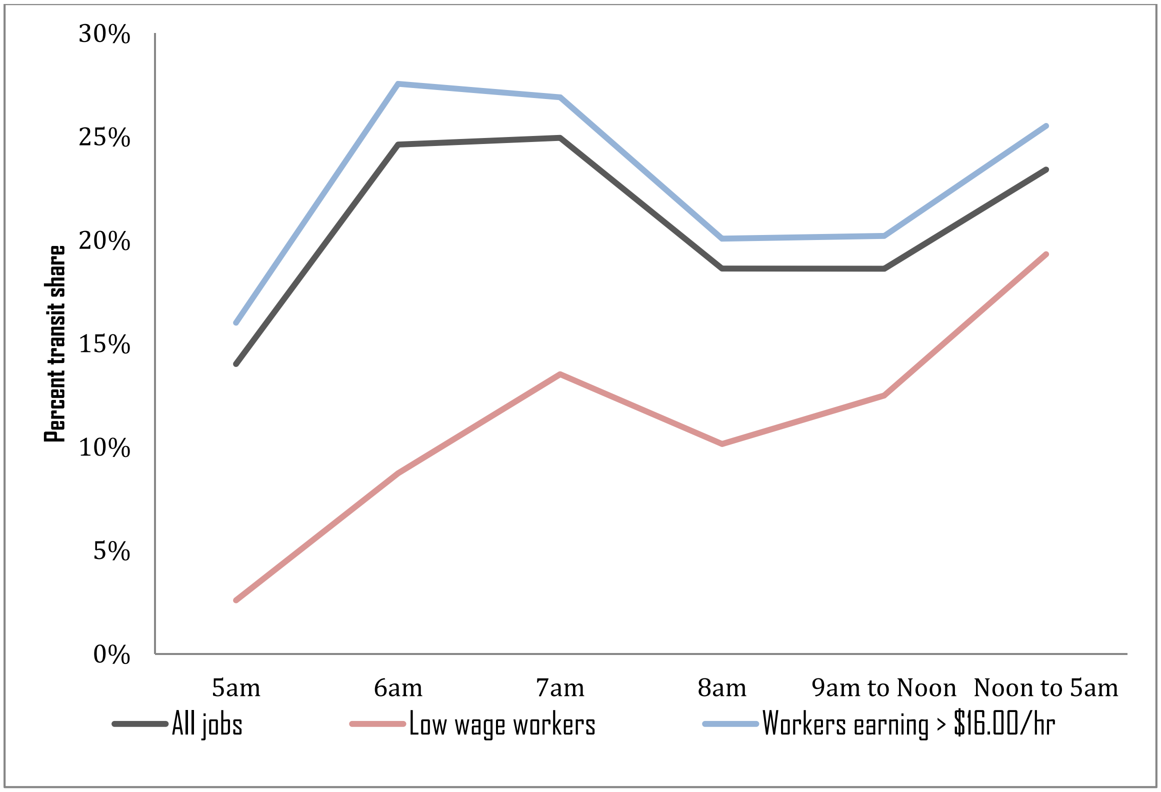

FIGURE 2 Transit mode share during the day

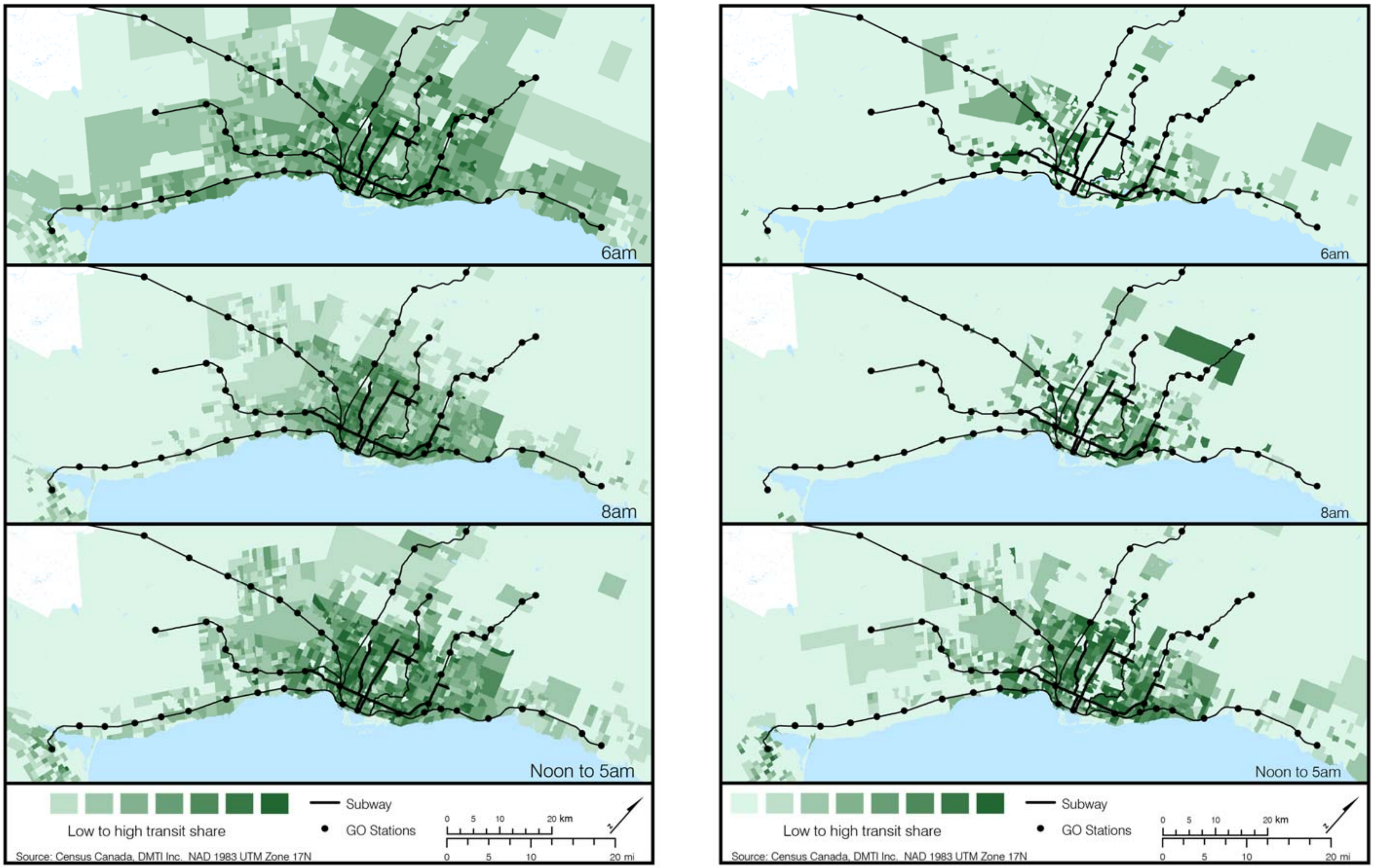

FIGURE 3 Transit mode share for higher-wage workers (left) and transit mode share for low-wage workers (right)

TABLE 2 Regression results

	6am			7am			8am		
	Total jobs	Low-wage	Higher-wage	Total jobs	Low-wage	Higher-wage	Total jobs	Low-wage	Higher-wage
Transit frequency[b]	0.003	0.035*	-0.005	0.012	0.048**	0.006	0.017*	-0.021	0.023**
In urban core	0.171***	0.078***	0.167***	0.134***	0.175***	0.111***	0.200***	0.217***	0.190***
In inner suburbs	0.120***	0.140***	0.119***	0.123***	0.190***	0.117***	0.154***	0.164***	0.149***
1km to subway station	0.385**	0.25	0.089	0.254*	-0.002	0.218	0.633***	0.692**	0.498***
1km to GO station	-0.027	0.447	-0.193	-0.144	0.371	-0.226	-0.04	0.292	-0.054
Distance to highway on-ramp†	-0.022**	-0.005	-0.022**	-0.015**	-0.018	-0.013*	-0.003	-0.009	-0.003
Social indicator decile	0.008***	0.014***	0.010***	0.014***	0.010***	0.015***	0.011***	0.008***	0.013***
Mean distance†	0.069***	-0.017***	0.049***	0.068***	-0.023***	0.045***	0.020**	-0.007	0.019**
Accessibility to jobs by transit[a]	0.019***	-0.014	0.024***	0.013***	0.013	0.015***	0.011***	0.018	0.013***
Constant	-0.027	-0.019	0.017	-0.077***	-0.001	-0.028*	-0.071***	-0.03	-0.067***
R^2	0.529	0.234	0.463	0.731	0.338	0.674	0.78	0.319	0.753

	9am to Noon			Noon to 5am		
	Total jobs	Low-wage	Higher-wage	Total jobs	Low-wage	Higher-wage
Transit frequency[b]	0.019	-0.007	0.029*	0.029**	0.018	0.041**
In urban core	0.198***	0.191***	0.179***	0.206***	0.273***	0.183***
In inner suburbs	0.165***	0.165***	0.156***	0.192***	0.243***	0.170***
1km to subway station	0.299*	0.035	0.181	-0.017	-0.603**	0.231
1km to GO station	0.11	-0.787*	0.387	0.185	0.196	0.235
Distance to highway on-ramp†	0.003	0.008	0.002	0.001	-0.005	-0.006
Social indicator decile	0.018***	0.019***	0.018***	0.014***	0.020***	0.013***
Mean distance†	0.011	-0.018***	0	0.008	-0.018***	0.018
Accessibility to jobs by transit[a]	0.011***	0.015	0.015***	0.017***	-0.002	0.033***
Constant	-0.053**	-0.046**	-0.028	-0.018	0.001	-0.008
R^2	0.639	0.304	0.556	0.684	0.457	0.57

* $p<0.05$
**$p<0.01$
***$p<0.001$
† Variable/10
[a]: Accessibility /10,000
[b]: Frequency/1,000

Three variables are significantly and positively related to transit mode share across all job categories and time periods. If a CT is located in either the urban core or inner suburbs, transit mode share increases compared to other parts of the region. Furthermore, having a higher social indicator decile (meaning a CT is more socially deprived) is linked to higher rates of transit ridership. This confirms previous findings linking social deprivation with transit ridership (*2-5; 8; 17; 18*). What follows is a discussion of each variable's relationship to transit mode share. Highway proximity is not discussed because of its inconclusive effect.

Transit frequency is statistically significant and has a positive relationship with transit mode share for low-wage workers in the early morning (6am and 7am). For higher-wage workers, transit frequency is statistically significant and positive from 8am onwards. This may indicate a number of things: low-wage workers who have an early morning departure time are influenced to take transit if transit service is frequent at this time, perhaps because those low-wage workers with early start-times work in areas served by transit. For higher-wage workers, departing early while using transit seems not to be a concern, thus transit frequency is only significant after 8am.

We see a similar change when considering transit proximity. Being close to a subway station is significant for total jobs up until noon. This confirms previous findings regarding rapid transit proximity (*3; 5; 25*). However, by wage category, subway influence is much more complicated. It is positively related to transit mode share for both low-wage workers and higher-wage workers at 8am. Yet, it is negatively related to transit mode share for low-wage workers between noon and 5am. In other words, at 8am, proximity to the subway is an important factor potentially influencing transit mode share. However, for low-wage workers with afternoon or evening jobs, other factors, such as little transit service to their destinations at these times or for their return journey (which is most likely in the early morning) may dissuade these workers from using transit, even if they live close to a subway.

Proximity to a Go-Train station has little demonstrated relation to transit mode share, and where it does, this relationship is negative (between 9am and noon for low-wage workers). This may indicate a mismatch between where Go-Trains serve and where low-wage workers need to travel to at this time. The majority of GO stations are located outside of the urban core of the City of Toronto. Also, this regional service is geared towards ferrying commuters between suburban locations and downtown Toronto. For low-wage workers, being close to a GO station at this time may simply indicate that they live outside of the urban core, and this type of residential location has a negative relationship with their transit use.

Furthermore, the effect of mean commuting distance switches with job category. Cervero and Kockleman found that mean distance between home and work locations has a negative effect on non-personal vehicle ridership, meaning it has a potential negative effect on transit mode share (*23*). This finding is partially supported in our results. In our case, mean distance has a negative effect on transit ridership for low-wage workers at all time periods except at 8am. However, for higher-wage workers, an increase in mean distance is linked to greater transit ridership up until 8am. Afterwards this variable is insignificant. These findings further substantiate the claim that it may be difficult for low-wage workers to commute using transit at certain times. For low-wage workers, an increase in distance between their home and job may make a commuting trip by transit more inconvenient compared to other modes. For higher-wage workers, an increase in distance may make a commuting trip by transit more convenient in the morning compared to other modes, especially if it ends downtown.

The most unexpected finding from this study is that transit accessibility at any time period has no statistically significant relationship with ridership for low-wage workers, a finding which is somewhat contrary to common conceptions of the relationship between income, transit use, and accessibility (*12-14; 21; 37*). Foth et al. (*3; 21*) showed that accessibility has the smallest transit mode share effect for those working in manufacturing, construction, and transport. However, income variation in this NOC category is quite broad, which means conclusions made between income and accessibility are limited in their case (*31*). One possible explanation for our results is that low-wage workers are captive riders. They will take transit whether they have high accessibility or not. This possibility seems less likely considering that other factors (proximity and frequency of transit, mean distance travelled) have an influence on their transit mode share, indicating that they may have some choice when it comes to transit use.

In contrast, accessibility is positively associated with transit ridership for higher-wage workers at every time period. By looking at the change in influence over time we see a pattern emerge. An additional 10,000 jobs accessible at 6am increases their ridership by 2.4%. This influence then declines, reaching its nadir at 8am. Afterwards it starts to increase, reaching its peak between noon and 5am, where an additional 10,000 accessible jobs results in a 3.3% increase in transit mode share. This finding may be of particular interest to local transportation and planning agencies. Increasing accessibility in the afternoon and evening may have the most effect on increasing ridership for higher-wage workers.

CONCLUSION

This study investigates how variables have a fluctuating relationship with transit mode share during the day. Many transit mode share studies use data that represent one time period, usually the morning travel peak, combined with job data that represent the entire day. This study looks at transit mode share at six time periods to demonstrate that different departure times have different transit mode share rates, and that variables' relationship with transit mode share also vary according to time period and job category. Understanding these daily fluctuations in travel behavior will allow researchers and transit agencies to more adeptly predict demand and need in transit service. Two important findings from this study are (1) that low-wage workers always have a lower transit share than higher-wage workers and (2) that accessibility has no effect on transit mode share for low-wage workers, at any time period.

The GTHA is a vast region, containing a large share of Canada's entire population. If transit mode share is to grow in this region then adequate transit availability during non-peak hours may be the key. It is also important to realize that low-wage workers may be having a difficult time using transit to reach their jobs at certain times. Noticing that low-wage workers demonstrate a number of key differences from their higher-wage counterparts substantiates this finding: In addition to accessibility's lack of effect, being close to a subway station has a negative effect during non-peak hours; potentially indicating that although transit service may be close to their homes, the destinations they can reach using transit at these times may not be satisfactory. Finally, low-wage workers are less likely to take transit because of lengthy distances between their home and work, indicating that as distance increases the ease of covering that distance using transit may decrease. In contrast, for higher-wage workers, an increase in distance is positively related to transit ridership in the morning (from 6am to 8am), demonstrating that an increase in distance may, in some instances, mean an increase in the ease of using transit for that trip. This may also indicate that higher-wage workers are much more likely to travel to the downtown area, which is easily accessible by transit, versus low-wage earners, whose employment locations are perhaps more evenly dispersed throughout the region. Future research into the spatial locations of different wage groups' homes and employment could help elucidate this point, the lack of which is a limitation of this study. Also, the influence of transit fare on low-wage ridership can have a crucial effect.

Metrolinx is tasked with coordinating and planning transportation investment and service in the GTHA. The agency's most recent transportation plan, the Big Move, predicts that transit ridership will double over the next two decades in this area. Understanding the non-peak travel needs of different working groups will be important to both local and regional transit service providers. Scheduling during non-peak hours and providing transit service to destinations not frequently served (e.g. outside the urban core) may have more or less of an influence on ridership depending on variables studied in this paper, a topic worthy of more investigation. The ability to provide convenient transport to a diverse set of areas at a variety of times will be the challenge faced by Metrolinx and its regional partners in the future. The Big Move recognizes this challenge, noting that transit trips crossing intra-regional boundaries are inconvenient, frustrating, and unattractive, not to mention costly (*50*). Research into the most cost effective and beneficial approach to this challenge is needed. The most important finding of this study, however, is that people's need to travel to work throughout the day, not just between 6am and 9am, is important. These needs also fluctuate depending on one's wage. These finding should be taken seriously when assessing which level of transit service is adequate, and to whom. By more accurately understanding daily transit needs, agencies can adequately and efficiently serve these needs.

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