Measuring Accessibility to Rail Transit Stations in Scarborough: Subway vs. LRT

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1 EXECUTIVE SUMMARY

This study compares the accessibility to rail transit stations in Scarborough for two alternative transit development plans, namely: a one-stop subway extension called the Scarborough Subway Extension (SSE) and the seven-stop Light Rail Transit (LRT).

This study uses Google Maps to determine transit-based trip times and distances from 123 neighbourhoods (Census Tracts) comprising Scarborough to each of the rail-based transit stations for the two options mentioned above. The study also computes trip times and distances to stations on the operating Scarborough Rapid Transit (SRT).

The study finds that compared to the LRT option, the average trip by public transit to the nearest rail-based transit station will increase by 1.4 km for the SSE option. On average, it would take six to seven minutes of additional time on public transit to get to the nearest SSE station.

The average trip time by public transit to the nearest SSE station is estimated at 27.3 minutes. By comparison, the average trip time by public transit to the nearest LRT station is estimated at 20.4 minutes. The accessibility to SSE stations will be worse than that for the existing SRT line where the average trip time by public transit to the nearest SRT station is estimated at 23.6 minutes.

The scope of this study is limited to determining the differences in public transit travel times to the nearest rail-based transit station on the proposed SSE and the LRT lines from various trip origins in Scarborough. The public transit travel times and distances are estimated using the current public transit schedules and routes.

2 BACKGROUND

This brief report documents the findings from a study to determine public transit access to rail-based transit stations in Scarborough. The Scarborough Rapid Transit (SRT) line currently operating between Kennedy subway station and the Scarborough Town Centre (STC) has now reached the end of its service life after nearly 32 years. Debates over replacing the line have resulted in the following options:

1. Replace the rolling stock for the existing SRT, maintain the track and stations, and continue service in the corridor.[1]
2. Replace the SRT by extending the subway from Kennedy Station to Scarborough Town Centre (STC). This option is primarily known as the Scarborough Subway Extension (SSE).
    a. Initially, SSE option supported intermediate stops between Kennedy Station and STC. However, given the recent higher cost estimates, the SSE option was reduced to a one-stop subway extension where the subway would run from the existing Kennedy subway station in a 6 km tunnel to its terminus at STC.[2]
3. Replace the SRT with a new seven stop Light Rail Transit (LRT), which would connect trip attractors and generators (such as Centennial College and STC) to the LRT service.[3]

This report estimates the overall accessibility from neighbourhoods in Scarborough to rail-based transit stations for the three alternatives mentioned above. Given that the SSE option results in a single new subway station at STC, Scarborough residents would have to travel longer distances to get to the subway station at either STC or Kennedy. Although a fewer station configuration would lead to an obvious conclusion, one still needs to quantify the magnitude of excess trip distance/time that Scarborough riders will experience with the SSE option in comparison to LRT or SRT options.

Further, this study generates public transit-based travel times from the 123 neighbourhoods comprising Scarborough to transit stations on the three alternatives (i.e., SRT, LRT, and SSE) using Google Maps API that relies on current public transit routes and distances.

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[1] Kalinowski, Tess (2015). Skip the Scarborough subway and modernize the SRT, says transit expert. *The Toronto Star*. Nov. 15, 2015. https://www.thestar.com/news/gta/transportation/2015/11/15/skip-the-scarborough-subway-and-modernize-the-srt-says-transit-expert.html. Accessed on March 27, 2017

[2] Due to proximity to Smart Track, the alignment was shifted east to McCowan Road.

[3] The existing SRT right-of-way/corridor would be used.

3 METHODOLOGY

This study uses publicly available resources to determine public transit-based access times and distances to the existing and proposed transit stations for SSE and LRT. The study thus confines its scope to neighbourhoods in Scarborough.

The study delineates the former municipality of Scarborough, now part of the amalgamated City of Toronto, into mutually exclusive and collectively exhaustive zones or neighbourhoods. The study relies on the 2016 Census that divided Scarborough into 123 Census Tracts (CT). Statistics Canada defines CTs as geographic areas with a population between 2,500 and 8,000.[4] The study follows the standard practice in travel demand forecasting to delineate a study area into Traffic Analysis Zones (TAZ) and assumes that all trips originate at, or are destined to, the centroid of TAZs. The 123 Census Tracts act as the TAZs for this study. The study assumes all trips to originate/terminate at the centroid of the CTs or neighbourhoods. TransCAD, a travel demand modelling software, has been used to obtain the longitude and latitude for the centroid of each Census Tract.[5]

Figure 1: Scarborough neighbourhood (Census Tracts) boundaries identified in blue

[4] http://www12.statcan.gc.ca/census-recensement/2011/ref/dict/geo013-eng.cfm
[5] http://www.caliper.com/tcovu.htm

In the past, determining travel times and distances from specific origins to destinations required the development of extensive travel-demand models. Such models usually require months, if not years, to develop and maintain, and are very expensive. For these very reasons, often such travel demand models remain proprietary. Even if more than one version of the travel-demand model exists for a city -- for example alternate versions of the model could be maintained by a university, the city government, and private consultants -- the mechanics of these models, and more importantly the assumptions made to generate the outputs, remain inaccessible to the public.

The study team selected a methodology that allows for reproducibility of findings. Therefore, this study used Google Maps to estimate travel times between origins and rail transit stations in Scarborough.[6] Given that Google Maps is publicly available, and is being used by millions of Toronto residents to plan their daily trips, it adds to the behavioural validity of this work because travel times and distances being estimated are available to individual travellers who often plan their trips after consulting Google-generated time and distance estimates.

Most travel-demand models have certain limitations. The models are often estimated to model travel during morning peak periods. Thus, the output from these models is less representative of the off-peak travel. Secondly, travel-demand models often do not replicate the physical street network in the digital network used for modelling. Instead, demand models use an approximate version of the street network, which includes freeways, arterials, and major streets. However, smaller streets, which are important for walking to and from bus stops, are not completely represented in the digital street network. Google Maps does not suffer from these limitations in the study area and offers a comprehensive representation of the physical street network.

Another reason for using Google Maps is the comprehensive way in which it estimates the total travel time for public transit. Consider the following example where a transit rider starts her journey at the condominium complex located at 2460 Eglinton Avenue East, situated across the street from Kennedy subway station. Her destination is Scarborough Town Centre. She enters addresses for a trip origin and destination in Google Maps.

The Google computational engine works behind the scenes and produces the output depicting travel times and distances for walking, biking, automobile, and public transit. The output for public transit is further detailed by the availability of transit services depending upon their operating schedules for the day. Thus, based on the trip start time, the trip times estimated by Google Maps will include wait times for the next available transit vehicle (e.g. bus, subway, or streetcar), in addition to walk times to transit stop and stations. Google Maps also identifies the bus and transit routes needed to reach the destination and offers information on alternative routes by public transit with comparable travel times. The aforementioned transit trip is presented in Figure 2.

[6] https://www.google.ca/maps

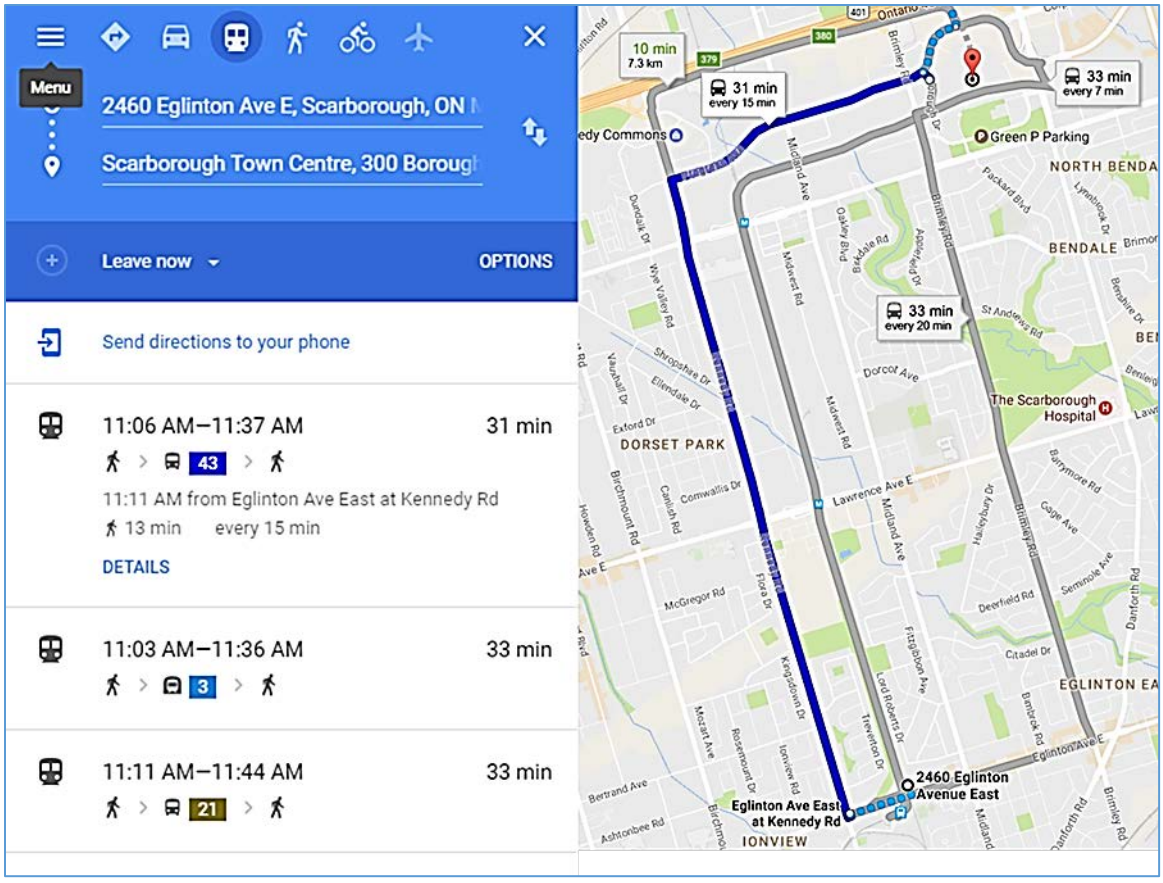

Figure 2: Sample transit trip in Scarborough

Note that the journey times reported in Figure 2 account for the following components of a typical public transit trip:

1. Walk to the transit stop (bus stop)
2. Wait for the next transit vehicle
3. Travel on board transit vehicle to destination or transfer to another transit vehicle
    a. In case of a transfer, include wait time for the next transit vehicle/s
4. Alight at the transit station/stop nearest to the destination and walk to the destination.

The above discussion also explains why Google Maps based transit times return slower bus transit operating speeds than what is often reported in textbooks and reports by transit agencies. Bus transit operating speeds are often listed at 15 to 20 kilometres per hour (or 3 to 4 minutes per kilometre). However, these speeds are exclusive of walk and wait times for transit riders. When one accounts for the walk times to and from transit facilities (access and egress), and wait and transfer times, transit riders experience a slower bus transit performance at 4 to 5 minutes per kilometre for their door-to-door trip.

Relying on the existing reports on transit alternatives in Scarborough, we took the best estimate for the location of the proposed LRT stations and obtained geocodes (X and Y coordinates) for the proposed transit stations using Google Maps.

3.1 Extracting Data From Google Maps

The study team had two options to automate several thousand searches needed to determine travel times for different modes of travel at various times during the day for trips originating in one of the 123 neighbourhoods and SSE/LRT stations. One option was to code and test a new algorithm. The other option was to search for an existing algorithm that could accomplish the same task.

The study team searched for such an algorithm for the commonly used GIS and statistical analysis platforms. Initially, the team intended to use an algorithm coded in Stata.[7] Regrettably, after testing the algorithm over several days, it was determined to be no longer functional given the changes made over time by the Google engineers. The study team tested several other similar user written codes and found them to be ineffective.

Fortunately, an open-source solution based on the R computing environment was determined to be robust for the task. Using the Gmapdistance package in R, we created a data set with the location details for all trip origins and destinations and estimated travel times and distances by public transit to rail-based transit stations.[8]

The package requires one to register with Google Maps to obtain an API key to be able to run multiple searches. One needs a Gmail account to be able to secure the Maps JavaScript API. Details are available at the following URL:

https://developers.google.com/maps/documentation/javascript/get-api-key.

The following example illustrates the output from a typical query executed using Gmapdistance to determine the network-based, congestion-sensitive driving travel time and distance from Washington, DC, to New York City.

```
> library(gmapsdistance)
> results = gmapsdistance(origin = "Washington+DC",
+                         destination = "New+York+City+NY",
+                         mode = "driving")
> results
$Time
[1] 13668

$Distance
[1] 361722

$Status
[1] "OK"
```

Figure 3: Travel times and distances obtained using Gmapdistance and Google Maps.

[7] Ozimek, Adam and Daniel Miles. 2011. Stata utilities for geocoding and generating travel time and travel distance information. *The Stata Journal*. Vol. 11, No. 1. Pp. 106-119 (http://www.stata-journal.com/article.html?article=dm0053)

[8] https://cran.r-project.org/web/packages/gmapsdistance/

Notice that the software reports time in seconds, which was converted to minutes, and distance in metres, which was converted to kilometres in the final output.

The following table lists the names of transit stations and geocodes to identify their location. The location of the proposed transit stops is estimated and could be different based on various reports and assumptions.

Table 1: List of transit stations analysed for accessibility in the study

Scarborough Rapid Transit		
Station	**Coordinates**	**Lines**
Lawrence East	43.750499,-79.2713605	Scarborough
Ellesmere	43.764816,-79.276499	Scarborough
Midland	43.768448,-79.27218	Scarborough
Kennedy	43.73023,-79.264517	Bloor-Danforth
Scarborough Town Centre	43.7721,-79.257469	Scarborough
McCowan	43.772826,-79.252026	Scarborough
7-Stop LRT		
Station	**Coordinates**	**Lines**
Kennedy	43.73023,-79.264517	Same as SRT
Lawrence East	43.750499,-79.2713605	Same as SRT
Ellesmere	43.764816,-79.276499	Same as SRT
Midland	43.768448,-79.27218	Same as SRT
Scarborough Centre	43.775117, -79.253893	7-stop LRT
McCowan	43.776119, -79.243222	7-stop LRT
Centennial College	43.784950, -79.230959	7-stop LRT
Sheppard East	43.794546, -79.234693	7-stop LRT
Scarborough Subway Extension		
Station	**Coordinates**	**Lines**
Kennedy	Same as SRT	SSE
Scarborough Town Centre	Same as SRT	SSE

4 RESULTS

Using algorithms outlined in the previous section, the study team estimated transit-based travel times from the centroid of each neighbourhood (123 Census Tracts in Scarborough) to the two SSE subway stations (the existing Kennedy Station and the proposed STC station), and to each of the seven LRT stations on the proposed LRT line.

The metric of interest is not the actual travel time or distance to each of the stations, but the difference in travel time between the shortest trip from a neighbourhood to an LRT station and an SSE station. Given that the proposed subway extension will have only one subway stop, the average transit rider in Scarborough would have to endure longer trips to

the one-stop subway extension than to the nearest LRT station. Despite this being an obvious conclusion, one still needs to quantify how much longer the trips will be for Scarborough transit riders spread across 123 neighbourhoods.

The study team determined the difference between the shortest trip to an SSE station and an LRT station for each of the 123 neighbourhoods. This way, one can see how transit service would be impacted by eliminating the current SRT stops or the proposed LRT stops and replacing them with just one subway stop at STC.

The results are presented in the following table.

Table 2: Excess travel by public transit in Scarborough resulting from the one-stop subway extension

	Average transit time from all CTs to the nearest station (minutes)	Average distance to nearest station (km)	Minutes/ km	Average Excess Commute: Difference in distance with SSE (km)
SRT	23.6	5.3	4.5	0.8
SSE	27.3	6.1	4.5	0
LRT	20.4	4.7	4.3	1.4

The study finds that the average trip by public transit to the nearest transit station on the current SRT is 23.6 minutes. In comparison, an average Scarborough transit rider will spend 27.3 minutes to access the nearest subway station on the one-stop SSE. The shortest average travel time to the nearest transit station was observed for the proposed seven-stop LRT at 20.4 minutes.

Similarly, the average transit-based trip distance (6.1 km) to the nearest station was the highest for the SSE option. A Scarborough transit rider would travel on average 1.4 km longer to access one of the two subway stations comprising SSE than an LRT station. Stated otherwise, at an average door-to-door bus transit trip of 4.5-minutes per kilometre, the average transit trip to a rail station will be approximately six to seven minutes longer with the SSE option than the LRT option.

Figure 4 maps the difference in trip distances between the SSE and the LRT option. The darker green shades identify those neighbourhoods that would experience the greatest increase in public transit access times to the nearest rail-based transit station. This Figure also identifies the location of the proposed LRT stations. One of the highest increases in travel times to the nearest station is at the Census Tract nearest to the proposed Sheppard East LRT station. Without the Sheppard East LRT station, transit riders from this neighbourhood must travel to the nearest subway stop at STC resulting in a longer trip of 7.3 km that could take an additional 19 to 25 minutes. The lighter shades of green identify neighbourhoods that would have the least impact on transit-based trip times to access the nearest rail-based transit station.

Based on the exact time when the search was conducted on Google Maps, some Census tracts reported slightly shorter trips to an SSE station than to an LRT station. Given that both the LRT and SSE options include a stop at the Scarborough Town Centre, the slightly

shorter transit-based trip times or distances for the SSE option are primarily an artefact of the time of the day when the search was conducted and relevant bus schedules.

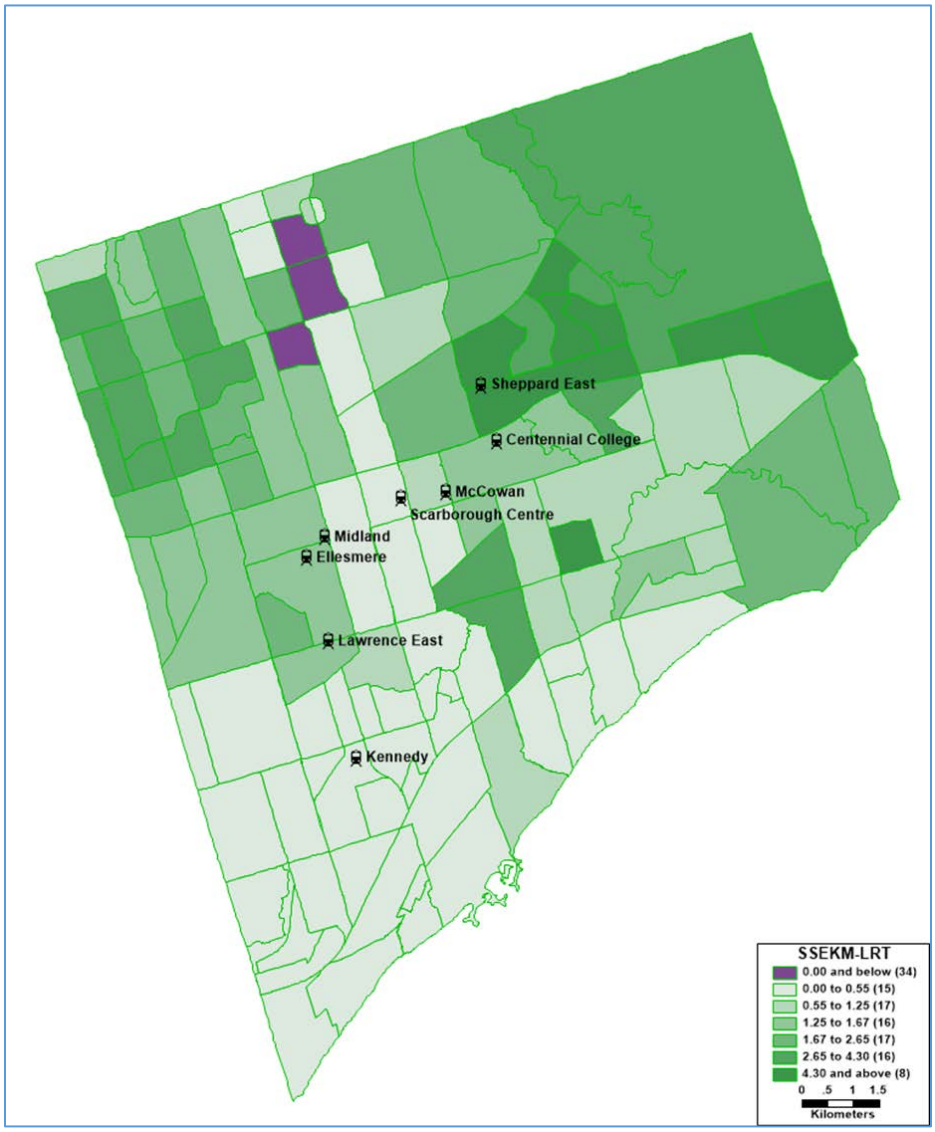

Figure 4: Excess travel for each neighbourhood between SSE and LRT options

Figure 4 shows that transit riders with trip origins and destinations in the immediate catchment of Kennedy and Scarborough Town Centre stations will see no meaningful change in accessing the SSE stations. Scarborough residents who are not in the immediate catchment of these two stations are likely to experience longer trips to get to the nearest subway station in comparison to an LRT station.

The excess travel to rail-based transit stations will vary significantly for riders based on their location in Scarborough. In the following paragraphs, the study presents the trip time differentials to transit stations for three neighbourhoods.

Table 3 presents the relative travel times and distances from three Scarborough neighbourhoods (Census Tracts) to the nearest transit station for the two alternatives, i.e.,

SSE and LRT. Transit trips from the first neighbourhood to the nearest transit station on SSE will be 7.3 km long taking 28 minutes to complete. Transit trips from the same origin to the nearest LRT station, however, will be 1.5 km long taking 8.7 minutes to complete. Thus, transit riders in this neighbourhood will spend 19 minutes or more on bus transit trying to access the nearest subway station.

In comparison, the second neighbourhood will experience only 1.4 km longer trips by bus to the nearest subway station relative to the nearest LRT station. Finally, the closest transit station for the third neighbourhood is Kennedy Station, and hence the residents of this neighbourhood will be indifferent to the SSE and LRT options.

Table 3: Trip time comparisons for three Scarborough neighbourhoods.

		Shortest commute to SSE			Shortest commute to LRT		
No.	Census Tract	Station	Kilometres	Minutes	Station	Kilometres	Minutes
1	0378.03	Scarborough Town Centre	7.3	28.1	Sheppard East	1.5	8.7
2	0376.06	Scarborough Town Centre	7.4	29.3	Midland	6.0	20.7
3	0355.05	Kennedy	3.4	20.9	Kennedy	3.4	20.9

Figure 5 presents the location of the three neighbourhoods and the nearest transit stations.

4.1 LIMITATIONS

The study relies on current transit schedules and operating characteristics to estimate travel times and distances. In the future, changes to bus transit operations will influence travel times and distances. More frequent bus services will reduce wait times, but if buses operate in mixed traffic, frequent bus service will not necessarily result in shorter trips. The exception is Bus Rapid Transit (BRT) where buses operate in their right-of-way, resulting in faster travel times.

In future scenarios for SSE, most bus routes will be rerouted to either Kennedy Station or STC, which may lead to additional congestion on arterials approaching SSE subway stations.

The study does not try to estimate the number of transit riders affected by the choice between SSE and LRT. Furthermore, given that the current debate about the future of public transit is focussed on two choices, the study does not make assumptions about the final trip destination of transit riders who, based on their final trip destination, could approach other rail transit stations in Scarborough.

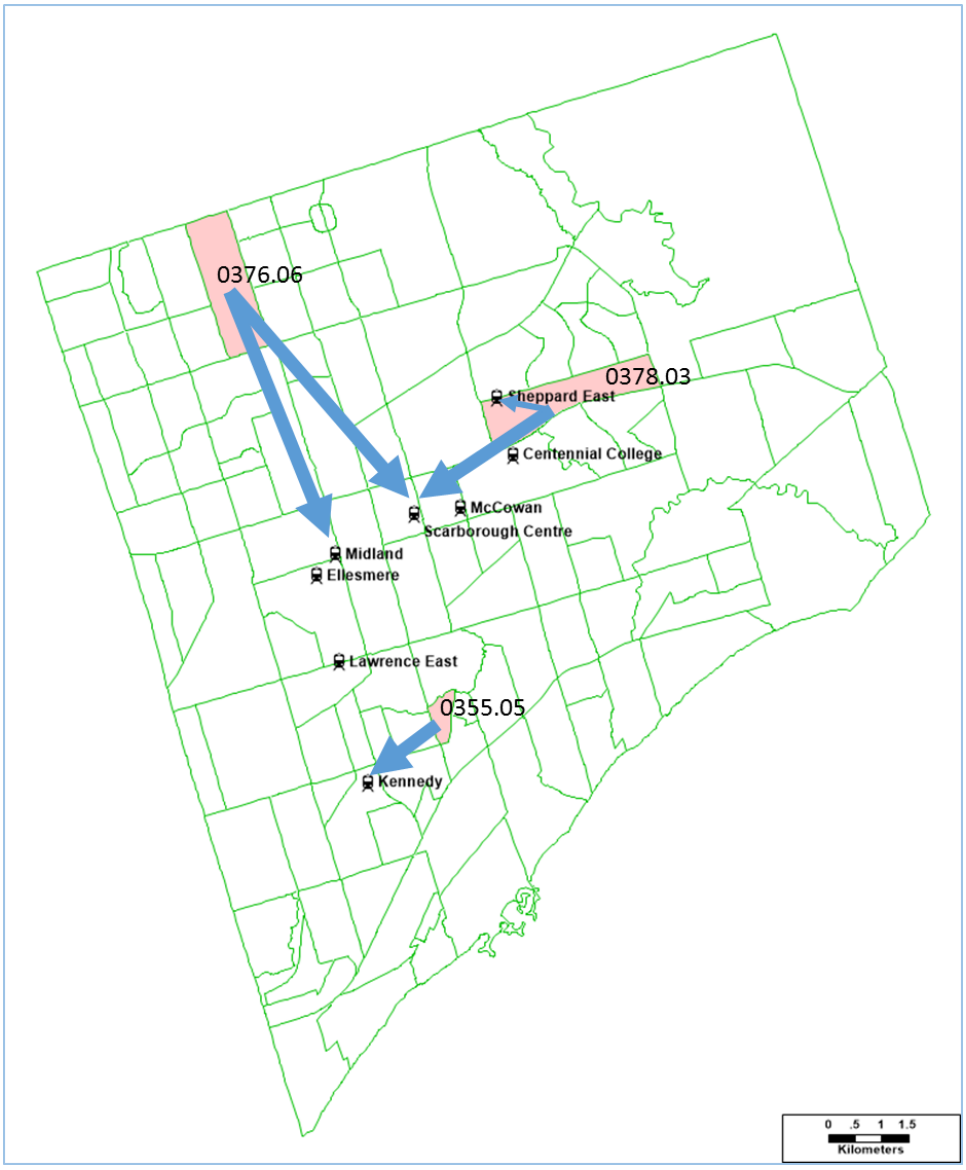

Figure 5: Comparative travel times from three Scarborough neighbourhoods to the nearest rail transit station

5 CONCLUSIONS

This study compares the public transit accessibility to the nearest rail-based transit stations for 123 census neighbourhoods in Scarborough. The study concludes that the average transit trip for Scarborough residents will increase by 1.4 km for the Scarborough Subway Extension (SSE) option compared to the seven-stop Light Rail Transit (LRT) option. The 1.4 km additional distance by public transit could take six to seven minutes longer for transit riders to reach Scarborough Town Centre (STC).

The average trip time by public transit to the nearest SSE station is estimated at 27.3 minutes. By comparison, the average trip time by public transit to the nearest LRT station is estimated at 20.4 minutes. The accessibility to SSE stations will be worse than that for the existing SRT line where the average trip time by public transit to the nearest SRT station is estimated at 23.6 minutes.

The staff at the City of Toronto has stated that trips originating at STC will be shorter by five minutes to reach Kennedy subway station and could be shortened by eight minutes for riders who are headed westbound beyond Kennedy Station.[9]

The modelling results reported by the City do not explicitly explain if the shorter travel times for trips starting at STC account for the excess travel Scarborough residents would have to endure to get to STC. Working from the assumption that shorter trip times reported for the SSE do not account for the longer trips on buses, this report raises the question whether gains in travel times for the SSE option will be significantly moderated, if not completely negated, by the longer trips transit riders would have to endure to get to the transit station at STC.

Based on the City's explanation of the modelling work, it is evident that any gains in travel times resulting from faster trips by the SSE option are essentially accruing to a small minority of Scarborough residents who will be able to start or end their trip at STC. The majority of Scarborough residents would have to take other modes of public transit to get to the STC that will take, on average, an additional six to seven minutes on an aggregate basis. This would negate any travel time gains, which are purported for the SSE.

6 RECOMMENDATIONS & OBSERVATIONS

This report recommends that any evaluation of alternatives for infrastructure development should be done as per the best practices in engineering economics where a comprehensive cost-benefit analysis is undertaken to compare competing alternatives. Based on the information released to date, it appears that a comprehensive analysis of alternatives to replace or refurbish the SRT has not taken place.

Essential details about the modelling work and assumptions that influence the results have also not been made public. This report recommends greater transparency in infrastructure decisions. Especially, the assumptions instrumental in determining the outputs from the travel demand modelling work should be shared with the public to understand the difference in ridership and travel time estimates generated by the modelling work commissioned by the City.

Details of the modelling work released by the City attributed shorter travel times for the SSE option over the LRT option to, among others, frequent SSE service that will make wait

[9] https://www.thestar.com/news/city_hall/2017/03/15/subway-lrt-srt-what-we-know-about-transit-in-scarborough.html

times shorter for the SSE option. Given the relatively modest ridership estimates at STC for both SSE and LRT options, it is not apparent why the LRT service might be less frequent than the SSE service.

Lastly, it will also be important to understand the difference in the scale and scope of the assumed intensity for residential, commercial, and other developments around STC associated with each transit option, i.e. SSE and LRT, and how it influenced the ridership forecasts.

7 ACKNOWLEDGEMENTS

The authors would like to thank Google for making it possible to estimate trip distance and travel times using the Google Maps computation engine. The authors are grateful to anonymous reviewers for their comments and edits. The authors would further like to express their gratitude to the programmers who coded Gmapdistance, which was used to estimate transit-based travel times and distances. Lastly, spatial analysis and mapping were done using Maptitude and TransCAD, which were donated by Caliper Corporation.

8 ABOUT THE AUTHORS

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[10] http://www.ryerson.ca/tedrogersschool/bm/programs/real-estate-management/murtaza-haider/
[11] https://www.redbooks.ibm.com/Redbooks.nsf/ibmpressisbn/9780133991024?Open

9 DISCLAIMER

The authors have volunteered to produce this report. The report was not commissioned, financed, or sponsored by any agency or institution. The sole purpose of preparing this report is to advance the dialogue on transit development in the Greater Toronto Area. While every effort has been made to ensure the accuracy and completeness of the contents of this report, the authors are not responsible for any errors or omissions, or for the results obtained from the use of this information.