A TALE OF TWO BRIDGES: USING THE 4-STEP MODEL TO UNDERSTAND ACTIVE TRANSPORTATION USAGE ACROSS THE WOLASTOQ/ST. JOHN RIVER IN FREDERICTON, NB

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1 Introduction

The City of Fredericton is a small Canadian city (2016 population of 59 405 (Statistics Canada, 2019)) that has embraced the development of its Active Transportation (AT) network with approximately 115 kilometers of non-motorized multi-use trails in the network (City of Fredericton, 2020), facilitated by the conversion of its abandoned railbeds into trails. The Wolastoq, as named by the Wolastoqiyik meaning the "beautiful and bountiful river" (renamed the St. John River) in Fredericton, New Brunswick separates the north and south side of the city. There are two river crossings approximately 600 m in length and 1.6 km apart that allow AT use: the Westmorland Street Bridge is used for both motorized and non-motorized users, the Bill Thorpe Walking Bridge (formerly a train bridge) is only for non-motorized users. A third river crossing, the Princess Margaret Bridge is for motorized users only.

The Westmorland St. Bridge provides more direct desire lines for origin-destinations to and from the north side of the city to the south and downtown, yet the AT volumes on the Bill Thorpe Walking Bridge are an order of magnitude larger. The assumption is that the difference of users between the two bridges is a function of a penalty that the user assigns to Westmorland St. Bridge; this bridge is a 4-lane highway bridge that is the busiest road in New Brunswick with the AT connection as a narrow sidewalk separated from traffic by a concrete barrier. The Bill Thorpe Bridge allows AT only and as a former train bridge, is served by a rails to trails network that connects throughout the city. The goal of the research was to create a 4-step travel demand model for active transportation in Fredericton to identify and quantify factors that influence the use of active transportation on two bridges in Fredericton. It was hypothesized that the users are assigning a generalized cost penalty to the Westmorland St. Bridge, effectively making the route appear to be costlier (e.g., longer) than the actual physical distance, which results in lower volumes. If a calibrated demand model could be created where AT volumes on the two bridges could be replicated, this would indicate that the difference in bridge AT volumes is to be expected and not a function of any aesthetic or user experience differences.

2 Background

The demand for Active Transportation (AT) is increasing in urban areas, yet most AT plans are qualitative, which means the demand is typically not estimated to the same degree as possible with vehicle-based plans. This is a broader issue in the engineering field. Many cities have AT plans and network upgrades laid out, but no discussions about any modelling completed and how the decisions were made or prioritized. There are limited resources within standard practice documentation to inform how to quantify AT travel demand, in particular for smaller cities. The Institute of Transportation Engineers (ITE) Transportation Planning Handbook (2016) states that "transportation engineers are beginning to gain a better understanding of the role and characteristics of bicycle and pedestrian movements, but there is still much to learn about their behavior". This handbook also states that the transportation planning field has a long way to go to develop tools and methods for analyzing walking and bicycling that are as sophisticated as those associated with motor vehicle modelling (ITE, 2016). There are several analysis methods and tools that ITE explained that can be used to estimate the travel demand for walking and bicycling, and these are divided into three major categories: tour-generation and mode-split models, GIS-based walk-accessibility model, and enhancements to the trip-based models (ITE, 2016). NCHRP 716 (2012), Travel Demand Forecasting: Parameters and Techniques is a standard practice document for travel modelling and notes that "the 4-step modelling process that has been the paradigm for decades is no longer the only approach used in urban area modelling" and notes that "nonmotorized modes are not yet included in all models, especially in smaller urban areas" (TRB, 2012). In terms of Canadian guidance, the main source is the Transportation Association of Canada Geometric Design Guide for Canadian Roads (Chiu, *et al.*, 2017), however this is primarily focused on geometric design for AT, with no guidelines for estimating demand of AT.

In July of 2021 the AASHTO council on AT created a Research Roadmap to review and summarize current research and relevant events happening in this field. This Research Roadmap aimed to assist the AASHTO Council on Active Transportation implement its Strategic Plan, which included goals and strategies related to research. Dill *et al*. (2021) noted that "the 4-step travel demand models have traditionally focused on motorized transport. However, using the process to better understand bicycle and pedestrian trips can help to understand development impacts, prioritize projects, plan active travel networks, and plan for AT user safety". Dill *et al*. (2021) also stated that "it is known that agencies have not been quick to incorporate AT modes into models, and the lack of widely available AT travel behavior data, relevant built environment data, and the focus on traffic analysis zone (TAZ)-level modelling has been a barrier preventing many planning organizations from incorporating AT modes into regional travel models". There is a growing amount of research on how to better incorporate these modes into models, with focuses on trip generation and mode split. There are still research gaps in detailed travel behaviour data, the impact of walking and bicycling trips, AT modelling methods and standardization (Dill, *et al.*, 2021).

The 4-step model (trip generation, trip distribution, modal split, trip assignment) connects demographic attributes to "trips", which are then synthetically organized into zonal origin-destination (OD) pairs as a function of the attractiveness of the zone in terms of travel time (i.e. generalized costs) and the magnitude of the trip attractions. These trips are then split into different modes as a function of the difference in generalized costs for each mode between each OD pair as a function of a modal split model, which are then assigned to the network based on the shortest path between zones. Other modelling techniques involve simulating users, though microsimulation models of pedestrians and cyclists are less developed compared to the vehicular traffic (Alsaleh & Sayed, 2020). Alsaleh & Sayed (2020) stated that "The Agent-Based Modelling (ABM) approach is an appealing and powerful approach for realistic modelling of road users' behaviour and their complex interactions in shared spaces. Compared to the 4-step travel demand model, Activity Based Modelling method considers the linkages among different trip purposes that a traveler might accomplish during a typical trip-making time period (ITE, 2016).

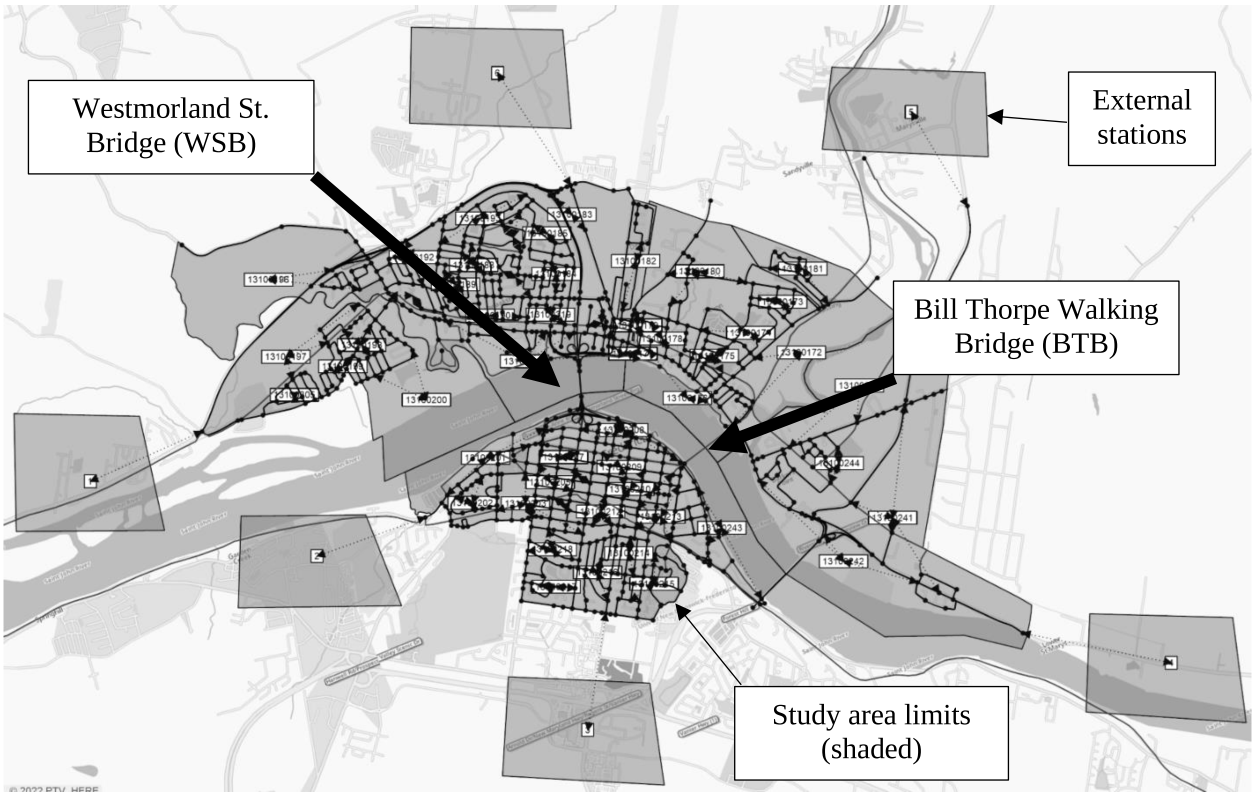
3 Methodology

Three types of data were used in this research. The first type was demographic and employment data for a subset of Dissemination Areas (DA) for Fredericton (a total of 54 within 13 Census Tracts) for the purpose of creating productions and attractions for the travel demand model. The second was AT traffic counts for both bridges provided by the City of Fredericton for calibration purposes. The third was non-traffic related data that might be useful in helping determine differentiating factors between the two bridges, including measuring sound levels, measuring entrance grades, and looking at climate data.

3.1 Demographic and employment data

The scope of this research included 54 Dissemination Areas (DA) within the City of Fredericton. These DA's are within 13 Census Tracts (CT); on either side of the rver, where both bridges allow for pedestrians and cyclists to cross. DA's are the smallest standard geographic area for which all census data are disseminated (Statistics Canada , 2018). Limiting the geographic size to areas surrounding the two bridges, as opposed to the entire City of Fredericton allowed for the model to be more sensitive to any changes in the network specifically around the two bridges. According to the 2016 Census Journey to Work data (CHASS, 2021), approximately 40% of people have a commute duration from private households with a usual place of work or no fixed workplace address of less than 15 minutes and another 40 percent have a commute duration of 15 to 29 minutes. The study area displayed encapsulates the majority of the people that would use the bridges for work, commercial or residential use.

Figure 1: Geographic scope of Fredericton AT model including external stations



Data sources included the 2016 Census dataset which was gathered from the Computing in the Humanities and Social Sciences (CHASS) Canadian Census Analyser from the University of Toronto (CHASS, 2021). This included data about Population and Dwellings, Age and Sex, Household Information, and Journey to Work all at the Dissemination Area level. This data was exported to an Excel file to be used for further calculations with trip productions and attractions. The census dataset at the DA level represents the travel behaviour of more than one individual; therefore this was aggregated data. One challenge that came with this data included that the model was not able to account for variability within a zone. Other data gathered was from the Canadian Business Patterns, Dissemination Area Level custom tabulation from the Scholars Portal Dataverse (University of Toronto, 2022). That included establishment counts by DA, 6-digit NAICS and average employment size range from 2016. To further organize and get only the study areas DA needed, the Beyond 20/20 Professional Browser was used to organize the data, which was then exported to an Excel file. Network speeds were determined through ArcGIS open-source data of the New Brunswick roads (City of Fredericton, 2021).

3.2 Traffic count data

Traffic volumes were determined by the City of Fredericton traffic counts, and pedestrian counts on both the bridges were provided by the City of Fredericton. The AT counts for the Westmorland Street Bridge were collected by the City, but the program Miovision was used to record and count the AT users for a period of 48 hours to get the modal split between walking and biking. The data helped to calibrate and validate the model after all steps of the 4-step travel demand model were completed. All volumes for biking and walking on the Bill Thorpe Walking Bridge were collected by the City of Fredericton traffic counters.

3.3 Differentiating data

Sound level data were collected on both bridges to determine the differences and see if this may be a factor influencing the use of AT. The sound was measured on both bridges with a handheld Mini Sounds Level Meter that meets IEC 652 Type II standards. Other information was collected including sidewalk widths and approach grades.

3.4 Travel demand modelling approach

After research of all the different types of modelling and software to use for this thesis, the 4-step travel demand model was chosen. Both simulation and the 4-step travel demand model allowed for travel demand modelling to be completed. Due to the complexity of simulation modelling methods, it would likely not be able to be calibrated quickly enough to begin scenario testing before thesis deadlines. More importantly, the model would require lots of data to be collected for the study area and small cities usually do not have the same amount of data collection as large ones. Data for larger cities can include household travel surveys, activity travel diaries, and detailed information on household socio-demographic characteristics. The 4-step travel demand model was chosen because it is a more straightforward approach that can rely on more readily available data inputs in smaller cities (such as the Census). The 4-step travel demand model was sourced from standard practice through the ITE Transportation Planning Handbook, 4th edition (ITE, 2016), and with technical guidance from the NCHRP 716 (TRB, 2012). Different software were compared such as EMME and QRS II, TransCAD and VISUM, and EMME and VISUM. Given each software package is approximately equivalent in their approach to 4-step modelling, VISUM was chosen as the researcher was already familiar with it.

Once the network setup was complete, then the demand model was created. This entailed selecting the person groups and creating the three trip types: Home-Based Work (HBW), Home-Based Other (HBO), and Non Home-Based (NHB). Then the transport modes were defined for the model, and this can be seen in Table 1 below.

Table 1: Demand Model Transport Modes

Mode	Code	Type	Max Speed (km/h)
Bike	B	Private (PrT)	15
Car	C	Private (PrT)	200
Walk	W	Public (PuT)	4

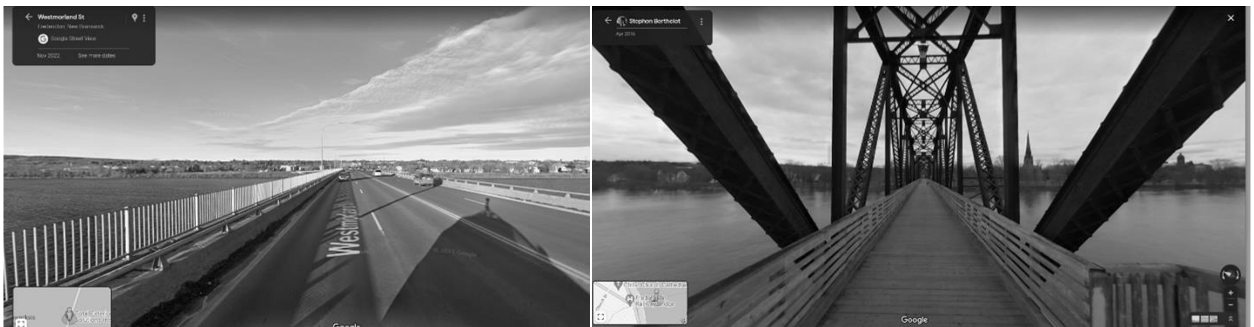
Walking was the only public mode of transportation, while both biking and car were private modes. Transit was neglected from this model due to the overall low mode share according to the 2016 census Journey to Work data, as well as the lack of supporting data to calibrate and validate with. For the link speeds, the car mode had a maximum speed of 200 km/h as it was a VISUM set speed but the velocities would never reach that high as they depended on the link velocities set throughout the model and City of Fredericton speed limits. The bike speed had a maximum of 15 km/h. This value comes from past studies completed by Lin, He, Tan & He (2008) and Mohamed & Bigazzi (2019), where mean operating speeds from thousands of riders were 14.81 km/h and 16.6 km/h respectively. The walking speed of 4 km/h was the VISUM set walking speed as well as the mean walking speed of pedestrians in urban environments, for example, in a study completed by Virkler (1998) in which the average walking speed was calculated.

The Beyond 20/20 Professional Browser was used to gather and organize all the employment data from the Canadian Business Patterns. The data only for the 54 DA's were then saved as an Excel file for easier processing and analyzing. Pivot tables were then used to organize the data and sort basic, service, and retail employment totals. Given that exact numbers of employees per zone were not available, the average values from the employment bins in the dataset were used to estimate number of employees. Trip attraction rates were used from NCHRP 716, as were deterrence functions for use in the gravity model for trip distribution (Table 4.5), based off a small MPO with a population between 50,000 and 200,000. The detailed procedure is available in the thesis by Burns that was used for this paper. Modal split models were initially taken from NCHRP 716 but replaced with a model for Los Angeles from NCHRP 365 (TRB, 1998) during the calibration process as Los Angeles had similar vehicle mode shares to Fredericton and gave more realistic results. "All-or-nothing" traffic assignment was used in the assignment step.

4 Bridge attributes: What are the differentiators?

Both bridges are approximately the same length, but as evidenced in Figure 2 below, they represent very different user experiences and very different usage rates. The Westmorland St. Bridge (left) is a four-lane highway bridge with the highest traffic volume in New Brunswick (51200 AADT, or 56230 person trips/day assuming 1.1 vehicle occupancy for Home Based Work) and a narrow sidewalk (it is not possible for two meeting cyclists to pass each other without dismounting). The Bill Thorpe Bridge allows AT only and as a former train bridge, is served by a rails to trails network that connects throughout the city.

Figure 2: Westmorland and Bill Thorpe Bridges (Google, 2023)

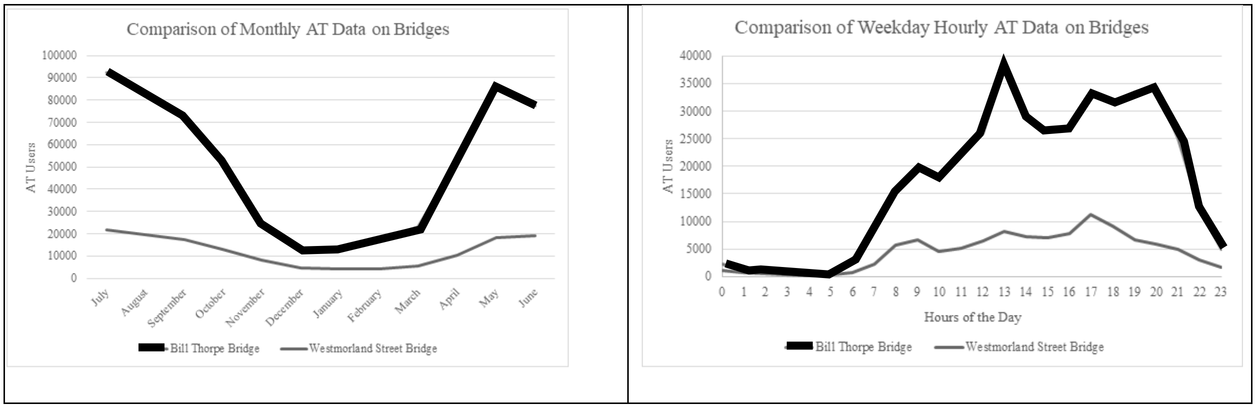


Westmorland Street Bridge	Bill Thorpe Walking Bridge
Walk 195 (person trips/day)	Walk 1397 (person trips/day)
Bike 205	Bike 266
Car 56320	Car - none
Avg. sound level (dB): 74.1 (AM), 74 (PM)	Avg. sound level (dB):49.2 (AM), 51.5 (PM)

The sum of the walking and biking volumes for the Westmorland Street Bridge came from the 2017-2018 full year of data. The percentage split for each mode came from the Miovision report where there were 49% pedestrians, and 51% cyclists. For the Bill Thorpe Walking Bridge volumes, these also came from the 2017-2018 full year of data, while the percentage splits were from data at the north end of the walking bridge where the counts were separated by mode. This resulted in a mode split of 84% pedestrians, and 16% cyclists. Sound levels were also measured on both bridges. The difference in sound levels is notable; 40-60 dB has been described as a "refrigerator hum" to "normal conversation", while "you may feel annoyed by the noise" for 70 dB (CDC, 2023.).

The data in Figure 3 show a much greater range in AT volumes on the Bill Thorpe Bridge on a monthly and hourly basis, likely as a function of the bridge serving as an important recreation link in the city. The Bill Thorpe Bridge has gentle approach grades and is separated from road traffic at either end.

Figure 3: Example of comparative AT volumes on both bridges



5 Model Calibration and Validation

The calibration process included a systematic way of adjusting factors and functions to first figure out the main source of deviation from the counts and included scenarios such as closing a bridge to AT to ensure total person trips/day crossing the bridge remained the same. The goal was to adjust factors to ensure that the volumes on both bridges were as close as possible to the values determined through the data collection process. During the calibration process the link volumes by the external station connectors were checked to ensure that the volumes were close to the ones referenced from the 2016 AADT map. Checking these values ensured that traffic productions entering the model were accurate. Table 2 below displays the link volumes near all six external stations in the model which were in the units of person trips, and the AADT from these volumes which were in the units of vehicle trips. The percent differences between the 2016 AADT values and the AADT calculated from the model were all within 5%.

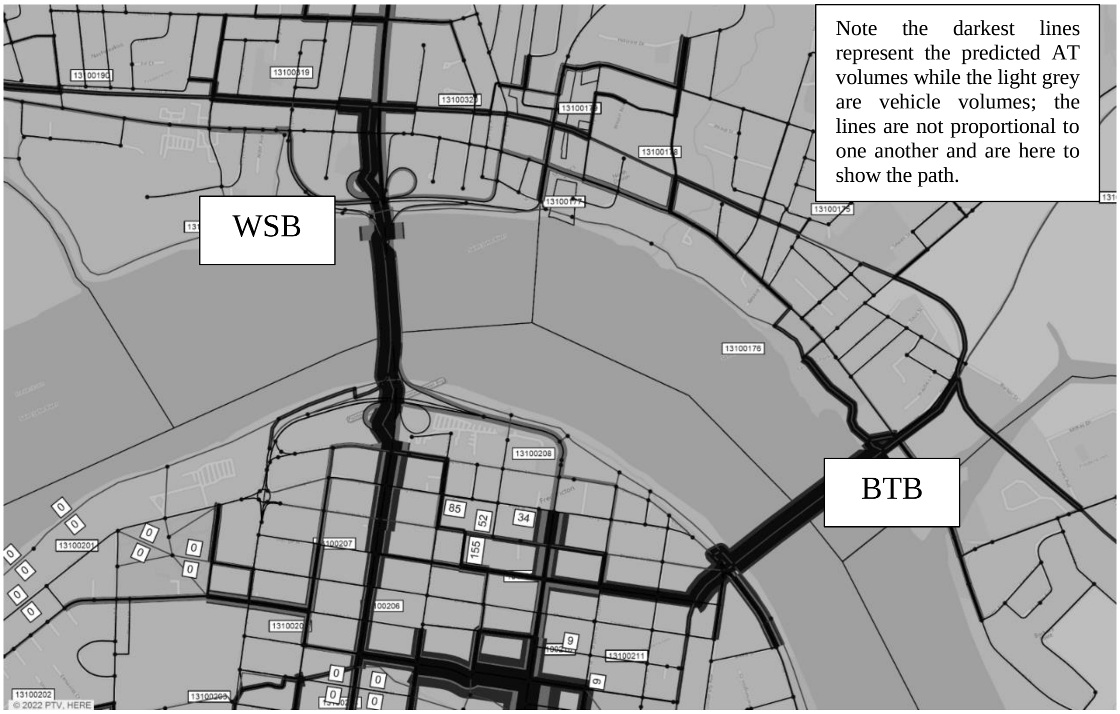
Table 2: Ensuring Model Calibration near External Stations

External Station #	2016 AADT values (veh. trips)	Link volume (person trips)	AADT calculated from model	% Difference
1	8560	13248	8372	2.2
2	7200	11691	7389	2.6
3	22500	34926	22073	1.9
4	6400	10392	6568	2.6
5	7190	11674	7378	2.6
6	6250	10353	6543	4.7

6 Scenario evaluation

This first scenario included balancing the travel demand model to calibration target values of the Bill Thorpe Walking Bridge. During the calibration process, it was discovered that calibration target values were not possible to achieve as the model could not be calibrated to the Bill Thorpe Bridge volumes without overpredicting walking trips on the Westmorland Street Bridge (WSB). Calibration during this scenario included testing different utility coefficients in the mode choice step of the demand model. The data in Figure 4 below show that it was possible to get reasonable link volumes on the Bill Thorpe Walking Bridge (BTB) that were close to the target values, and it was possible to Car volumes on the Westmorland St. bridge within 0.2% of target values, but walking and biking trips were grossly overpredicted. Note the darkest lines represent the predicted AT volumes while the light grey are vehicle volumes; the lines are not proportional to one another and are here to show the path.

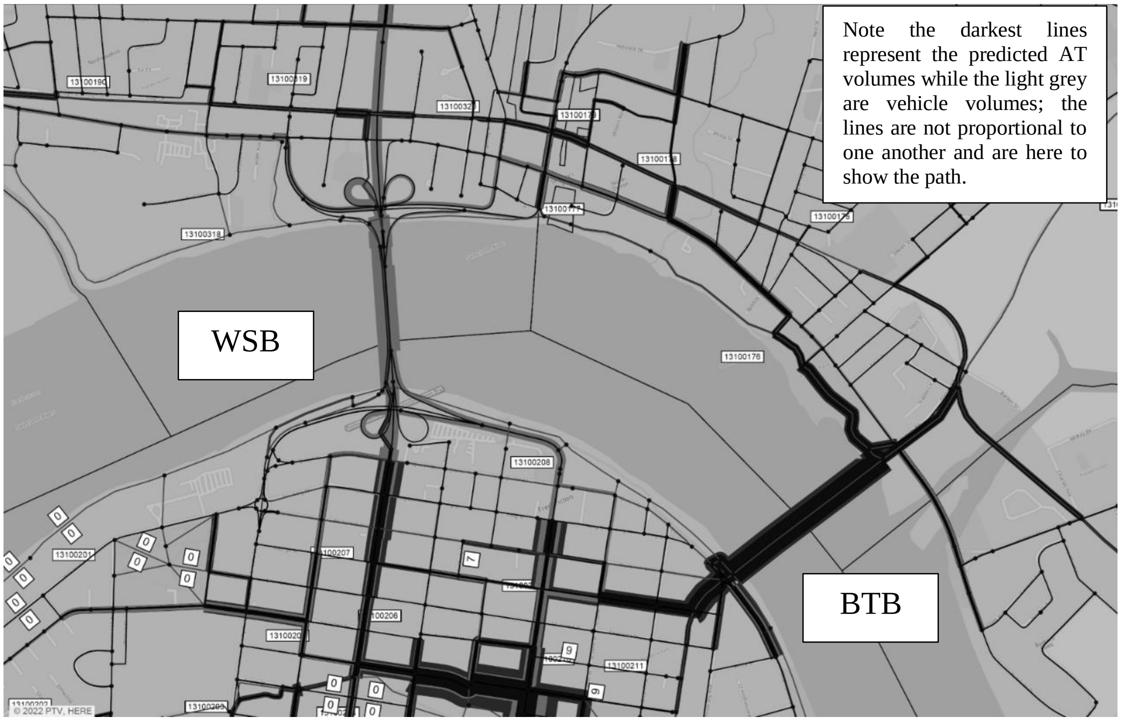
Figure 4: Traffic flow volumes, calibrating to the Bill Thorpe Bridge



	WSB			BTB	
	Walk	Bike	Car	Walk	Bike
Link Volumes	1311	161	56204	1333	238
% Diff. from Target Values	572.3	21.4	0.2	4.6	10.6

The next scenario included calibrating the model to try to reach the calibration target values of the Westmorland Street Bridge. For this, many different utility coefficients were again, researched and tried in the model, but none worked better than the coefficients from Scenario 1. Therefore, the only thing left to change was the AT link of the Westmorland Street Bridge to introduce a cost (i.e. distance) penalty so the link volume would be closer to the calibration target values. For this, utility coefficients stayed the same as the first scenario, and only the AT link length was changed. This involved manually changing the link length in both directions, recalculating the travel times due to the longer length, then re-running the skim matrices to calculate new travel times and distances. Then the entire model was re-run in VISUM and using the process of trial-and-error to slowly increase the length of the AT link on the Westmorland Street Bridge until the walking volumes reached the calibration target values. The length of the AT link on the Westmorland Street Bridge was increased by 1.515 km to be approximately 3 times the length of the original bridge before reasonable link volumes appeared on the Westmorland St. Bridge (Figure 5).

Figure 5:Traffic flow volumes, calibrating by increasing Westmorland St. Bridge length



	WSB			BTB	
	Walk	Bike	Car	Walk	Bike
Link Volumes	212	4	57160	1620	252
% Diff. from Target Values	8.6	97.8	1.5	15.9	5.3

Although the demand for pedestrians walking across the Westmorland Street Bridge was present as seen in Scenario 1, people appear to be assigning a penalty to this AT link in reality as the calibration target value was much lower. In this scenario, that penalty was a perceived length increase of over 1.5km or three times its original link length. This could be interpreted to mean there is a latent demand for approximately 1100 annual daily person trips who want to walk the Westmorland Street Bridge but were choosing not to.

7 Study limitations

Within the study there were some limitations with the modelling process and calibration of the 4-step model for AT demand. Firstly, the 4-step model used only aggregated data with the DA when there may be some variability house to house. This looked at zonal data as opposed to individuals. Activity-based models may be able to better capture the individual trips and the interconnection between trips but requires data that may not be available at a small city level.

Second, there was no recreational trip category in this model. Typically demand modelling has been focused more on home-based work, so there were limited data and coefficients for a recreational category. Recreational trips were captured in this model most likely in terms of Home-Based Other and Non Home-Based, but it would be difficult to determine what types of trips are crossing the bridges.

Next, using the 2016 Census Journey to Work data for Fredericton, provided some calibration for the models used in NCHRP 716, but was only limited to HBW work trips. Due to the limited data, the Journey to Work data was also used to aid the calibration of the remining two trip types.

Finally, limited data for AT modes and utility coefficients in standard modelling practices led to the use of NCHRP 365 HBW mode choice utility coefficients being used for all three trip types. It was interesting that the Los Angeles model used from NCHRP 365 gave the best probabilities as starting coefficients to reach the calibration target values. This city has one of the largest populations in the United States, with a very high demand for cars for its mode choice. Los Angeles model worked well for Fredericton despite it being a small and more rural city than compared to Los Angeles. Fredericton also has a very high mode choice percentage of people choosing to use their car, which is why this Los Angeles model may have worked so well.

8 Conclusions

The use of the 4-step model provided a mechanism to explain why AT travel demand on the two bridges in Fredericton was markedly different from what would be expected based on shortest path analysis. There is a user experience difference and this appears to be manifesting itself in terms of lower volumes on the Westmorland St. Bridge than there should be if users considered both bridges the same. According to the model, users assign a travel penalty that has them perceive the Westmorland St. Bridge (WSB) as three times as long as it actually is. This does suggest that if Fredericton could find a way to make the user experience on the WSB more like the Bill Thorpe Walking Bridge, it could attract over 1000 new person trips per day. This suggested that there is value for small cities using this approach for AT modelling, by using publicly available data and volume counts collected by the city, to help inform key infrastructure decisions.

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