Impacts of Potential Rail Crossing Closures on Active Transportation in Guelph, Ontario

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Abstract

Integrating new railway infrastructure into older neighborhoods is an essential part of sustainable city expansion, but what impact do these changes have on pedestrians and cyclists? Our study aims to assess the impacts of rail crossing closure(s) on active transportation users and routes. Using ArcGIS Pro's Network Analyst and further statistical paired t-test analysis we identified the impacts to 5 crossings with the city of Guelph. Overall our analysis highlights that closures have a minimal negative impact on pedestrians and lesser negative impact on cyclists. We did find that for pedestrians any closure scenario does slightly increase travel time and distance (mean = 49.65m and 35.95 seconds longer) and for cyclists most closure scenarios resulted in slight increases in travel time and distance (mean=11.94m and 2.26 seconds longer). We identified that the negative closure scenario impact on AT user travel is positively correlated with the number of crossings being closed.

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Introduction

With the progress of urbanization, there is an accumulation of humans and vehicles in urban areas (Jia, 2021). Integrating new infrastructure into older neighborhoods and providing more sustainable travel options is an essential part of sustainable city development, but what impact do these changes have on the local users? Encouraging active transportation is one way cities can meet their sustainability goals. It is commonly accepted that active transportation includes walking, bicycling, and mass-transit travel modes. (Rybarczyk 2018) Specifically using your own power to get from one place to another. (Government of Canada 2017). For the purposes of our research we will limit AT to the broad categories of walking and cycling. We then use the categories to assess issues of network change, accessibility, and impact for AT users.

Circumstances where individuals walk or cycle vary widely from necessity to personal choice of transportation. Regardless of reason when looking at cycling specifically individuals are shown to be most comfortable cycling on streets with physically separated infrastructure or very low volumes and speeds of motor vehicle traffic. (Book 18 page 17). It is important to account for these preferences when assessing the impacts of a network. Further, a better walking environment can enhance the livability of a city, ensure better access to public transport and help to combat climate change (Bhuiya, 2020). For these reasons it is essential to assess whether rail crossing closures (sustainable commuter train infrastructure improvements) have an impact on active transportation users.

To our knowledge no studies have addressed the impacts on active transportation route choices when a series of pre-existing crossing is altered/eliminated. We aim to address the question of "what happens to cyclists/pedestrians?" as these changes occur. Increases in commuter train services impact the frequency and speed of railway use which may necessitate changes to road-level rail crossings. We assess active transportation routes to inform future network choice. This is important since examining bicyclists' route choices provides valuable insights into the importance of road environments for bicycling (Fitch 2020). Specifically within the Guelph, Ontario context we aim to assess the impacts of potential changes to the level rail crossings to the transportation network (Guelph Rail Study 2021).

We will use GIS techniques to find how accessible key locations are on either side of each road-level rail crossings. We will utilize ArcPro's Network Analyst to build and analyze our network. Specifically, Arc allows the user to customize transport routing rules (Wallace 2014) which is ideal for our analysis. As well as finding how accessibility could change as different combinations of crossings are closed. Our results aim to address what combination of railway crossings (if any) can be closed with minimal hindrance to users as well as the direct impacts on travel times/least-cost pathway. Overall we aim to outline/identify the impacts (service area connectivity and travel times) of potential Metrolinx rail crossing closure(s) on active transportation users and routes within Guelph.

Research Objectives

1. Identify public service areas and points/data of interest for active transportation users within a 5000m (5km) range (cyclists) and within a 1500m (1.5km) range (pedestrians) from the rail crossings in question.

2. Combine street/trail data to develop an effective network base for our analysis.

3. Develop a GIS-based network model that assesses the path of least resistance for AT users when traveling across various rail crossings to access service areas.

4. Run the network model on all rail crossing closure scenarios and clearly assess the changes in AT connectivity and accessibility for each scenario using statistical t-test analyses.

5. Assess the strengths and limitations of the model/approach used.

Study Area

The research within our project focuses on key areas of Active Transportation at five studied crossings; Alma Street, Edinburgh Road, Yorkshire Street, Glasgow Street, and Watson Road. With Transport Canada's Railway Safety Act in mind, our research demonstrates which of the five crossings/combinations of crossings serve Active Transport (AT) users most. The recent expansion of a two-way-all-day Metrolinx rail service for the Kitchener Go rail line means that the City of Guelph must adjust to accommodate for the increased frequency and speed required for this rail service to operate. In order to increase the speeds at which this new service can operate through the city, there is a possibility that some rail crossings within the city may need to be closed (City of Guelph, 2022). Alterations to these crossings could impact active transportation (AT) users in the area of all ages and abilities which would directly go against the city of Guelph's 2019-2023 strategic plan for 'Navigating our future', which aims to invest in more affordable, connective, safe and efficient active transportation within the city (City of Guelph, 2020). The City of Guelph's study/research aims to provide enough information to make an informed decision as to the potential closure of Metrolinx rail crossings (if any). The Guelph Coalition for Active Transportation (GCAT) has identified these rail crossings and potential closures to these crossings to be of relevant concern for the state of active transportation in the city of Guelph (GCAT, 2021).

Our project has two buffer zones within our general study area of Guelph. The 5 road level Metrolinx rail crossings (at Alma St., Edinburgh Rd., Yorkshire St., Glasgow St. and Watson Rd.) are the center of the study area (City of Guelph, 2022). Additionally, all social services (schools, child care, food banks, etc.), public transportation bus stops and essential commercial services (grocery stores, pharmacies, banks, etc.) within these buffers will be included in our analyses within the buffered service areas. These essential services are of the utmost relevance to AT users in Guelph and as such are included as points of interest/destinations within our network to adequately assess the impact possible rail closures will have on proximal AT user access and to these services (GCAT, n.d.)

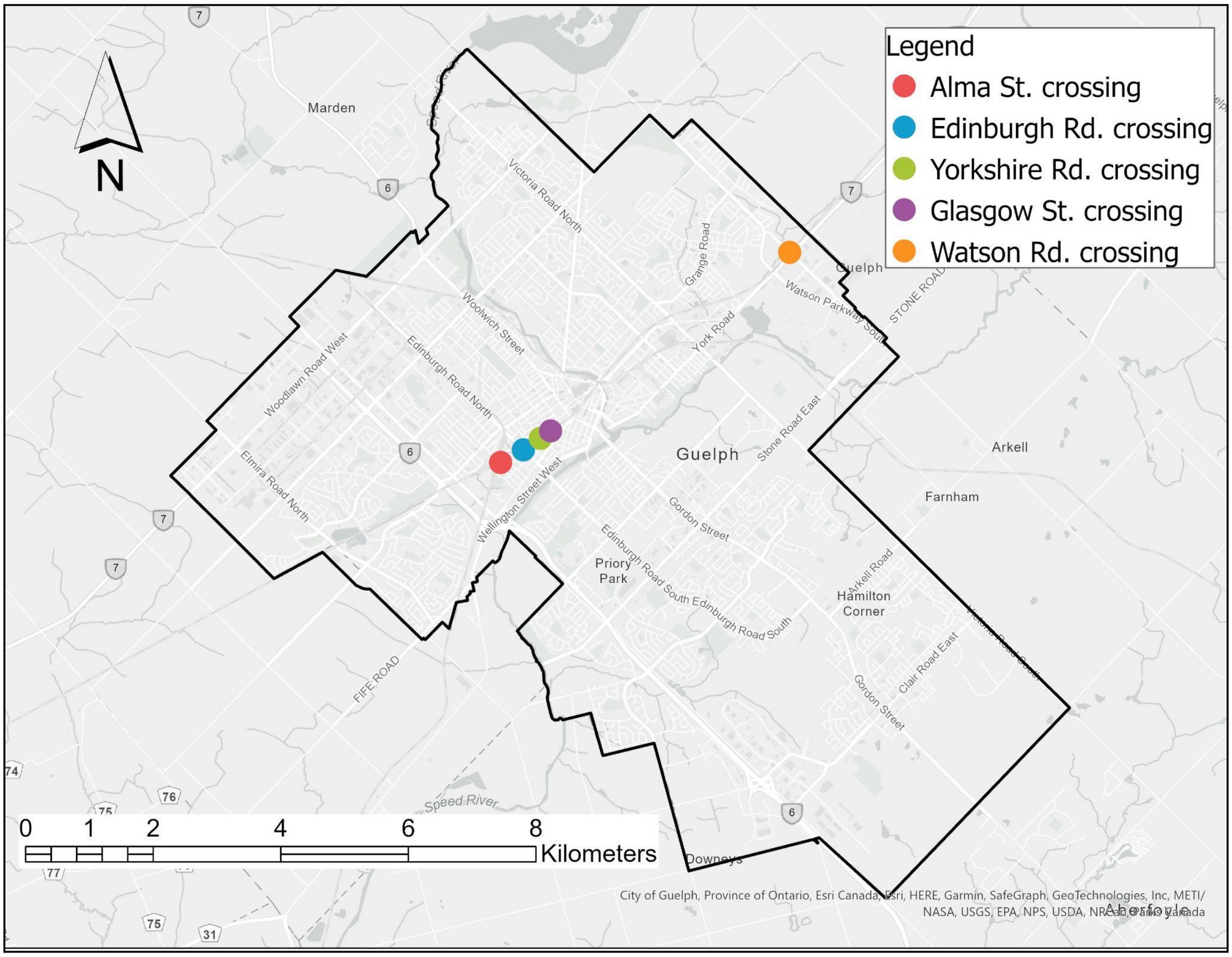

Fig 1: Map showing the locations of the 5 rail crossings along the Metrolinx rail lines (running NE to SW) within the city of Guelph's municipal boundaries.

Methods & Data

Objective 1: Identify public service areas and points/data of interest

We used a combination of GIS methods to assess the impacts on AT users through potential rail closures. The subject area in question (within the city of Guelph) has not undergone massive road level changes in recent years. As a result older datasets are used within this project. Further, we ensured all data was reprojected to UTM 17N.

Table 1: Data Used within our analysis

Variable	Date Updated	Data Source	Scale
OpenStreetMap	Updated 2022	Open Data Commons	City Scale
Route (RTE) File	Updated 2015	DMTI Spatial Inc.	Provincial Scale
Walking Trails	Updated 2017	City of Guelph	City Scale
Cycling Trails	Updated 2014	City of Guelph - Open Data	City Scale
Railway Line	Updated 2017	City of Guelph	City Scale
Elevation	Published 2021	Lake Erie 2018 1m High Resolution from CanElevation Series	Lake Erie Watershed
Bus Stops	Updated 2018	City of Guelph	City Scale
Schools	Updated 2016	City of Guelph	City Scale
Dissemination Areas	Published 2016	Statistics Canada	Country wide digital boundary

Our project has two buffer zones within our general study area. The buffers around these crossings will be at 1500m (1.5km) for the pedestrian AT analysis and at 5000 m (5km) for the cyclist AT analysis. These buffer distances serve to accurately capture a typical distance AT users would travel to access service areas using these rail crossings. The 1500m buffer value comes from a study on active transportation travel distances in the metropolitan area of Montreal, Quebec, which found that within the 85th percentile of pedestrians, travel distances were on average less than 1.5km (Larson et al. 2010). For cyclists, a study on motivators and deterrents for cycling in Metro Vancouver found that trips less than 5km were motivators for using cycling as active transportation (Winters et al. 2010). We also included AT users who use various forms of mobility devices within the 1500m buffer.

Start points for our analysis were created at road intersections within the buffer area. End points are then set as our points of interest. We determined that Bus Stops, Schools, Financial

Institutions, Healthcare Facilities, and Food Distribution Services that fall within the 1500m/5000m buffer highlight the key facilities needed within a community. These buffers show which paths can be reached within a reasonable timeframe and as a result which businesses/services are of greatest interest. These points were then used in our analysis as end destinations for the least resistance cost-distance analysis across different rail crossing path closure scenarios.

Objective 2: Combine data to develop our network

We developed two networks that incorporate walkable roads/trails, bike routes, and roads (with appropriate weightings for arterial roads). These networks are developed using openstreetmap (OSM) data as a base. The benefits of the OSM dataset shows arterial/major roads differently than smaller roads within a neighborhood. This will help us to highlight the best routes and reasonable service areas for active transport users. This creates a network that helps with further analysis through the ArcPro network analyst and enables us to engage with the complex connectivity scenarios associated with potential railway closures. Specifically within our scenarios we assumed all residential roads are walkable due to lower traffic volume; in contrast arterial roads which are only walkable if there is a sidewalk accessible. These networks are then used to run scenarios where crossings are either a viable path or an impedance factor for active transportation access to transrail service areas.

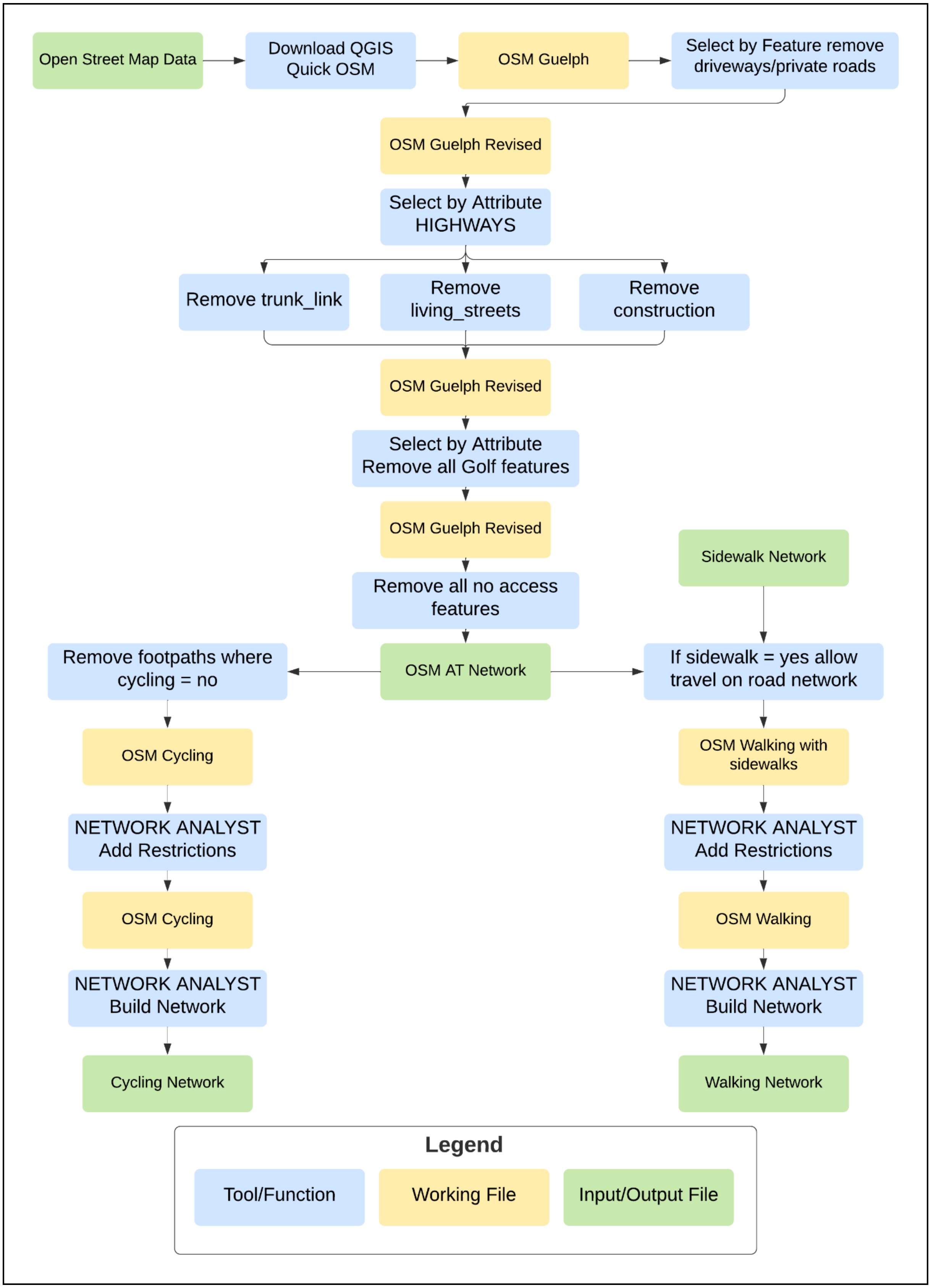

Fig 1: Network Development Process

Objective 3: Asses the path of least resistance

From a literature review we identified the prevalence with which certain important connectivity factors for AT were mentioned and ranked within those papers. The literature review (n=15) revealed three important factors for AT users as: distance, safety and effort. Under our network datasets we designated the network travel modes as either walking or other (cycling), in order to account for finding the shortest distance (in time) when conducting the analysis. To address the second and third relevant AT connectivity factors we assigned resistance classes (Tables 2-4) for safety factors (segment type and sidewalk presence) and for effort (slope) within the travel attribute section of the network dataset.

Three factors were most important to AT users:

1. Distance (time)
2. Safety (sidewalk/bike infrastructure and segment type)
3. Effort (slope)

Table 2: ArcPro Network Analyst Restriction Classes

Network Restriction Classes Hierarchy						
Prefer (high)	Prefer	Prefer (low)	Avoid (low)	Avoid	Avoid (high)	Prohibited

Table 3: Walking Network Route Resistance Factors

Class	Slope	Segment type	Other
Prefer (high)	<2%	Footway, Pedestrian, Path, Residential	Where there is a sidewalk present AND Where foot = yes, designated
Prefer	2.01%-5%		
Prefer (low)		Tertiary, Tertiary_Link, Service	Where sidewalk = yes or OSM_sidewalk = both, right, left, separate
Avoid (low)			
Avoid	5.01%-10%	Secondary, Secondary_Link	Where lanes = 4, 5, 6 and segment type is not residential
Avoid (high)	>10%	Primary, Primary_Link	
Prohibited		Track, Cycleway	

Table 4: Cycling Network Route Resistance Factors

Class	Slope	Segment type	Other
Prefer (high)	<5%	Cycleway, Path, Residential	Where bike lane = lane, shared, shared_lane
Prefer			If field bicycle = Yes designated
Prefer (low)	5.01%-10%	Tertiary, Tertiary_Link, Unclassified, Service	
Avoid (low)			
Avoid	>10%	Secondary, Secondary_Link	
Avoid (high)		Primary, Primary_Link,	
Prohibited		Track, Pedestrian	

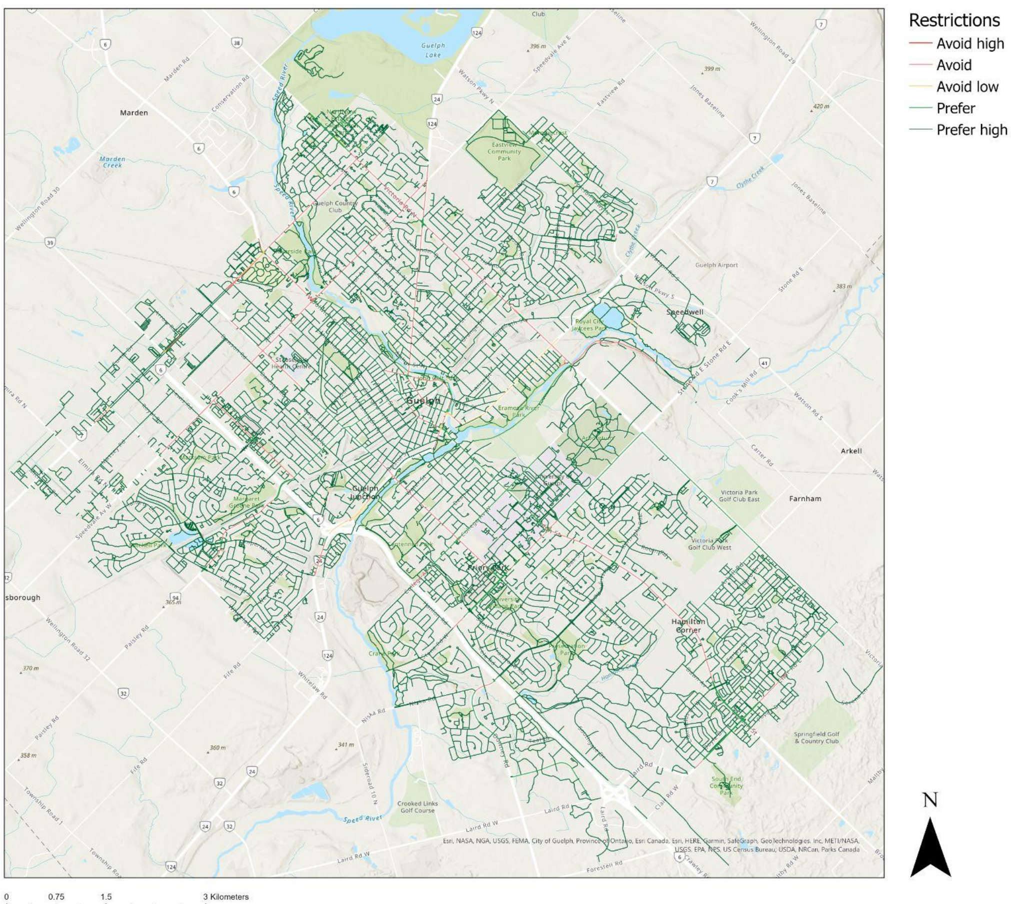

Fig 2: Visualization of the restrictions for the walking network based on walking infrastructure, slope, segment type, and number of lanes

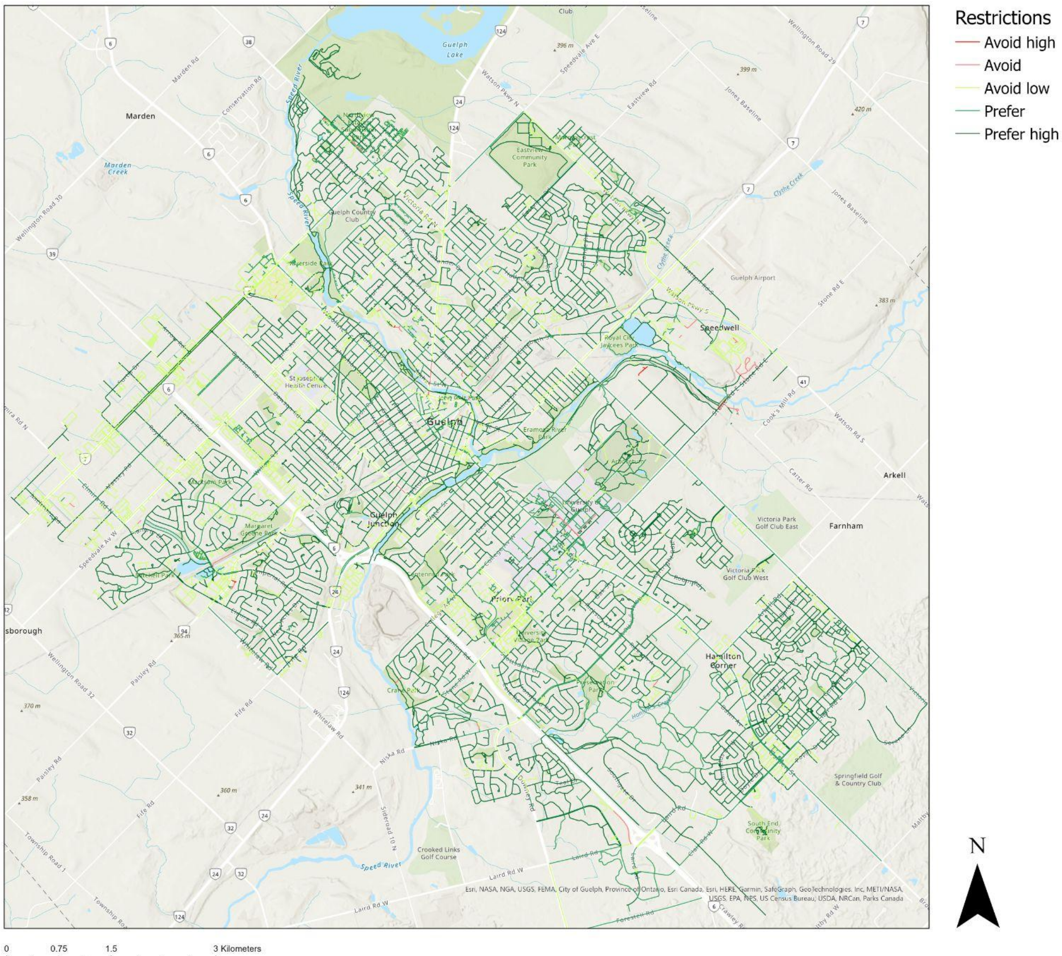

Fig 3: Visualization of the restrictions for the cycling network based on bike infrastructure, slope, and segment type

<u>Objective 4: Run the network model and assess impact</u>

We ran the network model on all rail crossing closure scenarios (where different service areas are being accessed in relation to different combinations of crossings closing) and assessed the changes in AT connectivity and accessibility for each scenario. We utilized the OD cost matrix within the Network Analyst. This tool finds and measures the least-cost paths along the network from multiple origins to multiple destinations (ESRI n.d.). We specified routing from one origin to one destination focused on routes that use the crossing as part of the least cost path. We also limited the cycling network to 5250 m routes and the walking networks to 1575 m routes. These are both the most common distances to travel cycling/walking with a 5% margin for anomalies. This step also included manually digitizing open/closed railway crossing information for consistent file formats (.shp files). This creates linear barriers across the rail crossings that we can plug into our model to simulate closing down particular crossings.

These scenarios were run by manually including the digitized open/closed railway crossing information from before into the network model. Each combination is run within the network model and the matrix array output is saved.Systematically all combinations of the five railway crossings have been simulated as closed. The results from our initial matrix analysis are presented in Appendix C.

Our findings are presented in a matrix outlining the effects of different combinations of closures on our network model. We then used R to do a pairwise t-test to identify any statistical significance between the unchanged scenario and different closure scenarios. These results are then visually presented and evaluated based on the cost of each route. These outputs have then been combined to better display the data as a whole without modifying or removing any results. These raw results can be found in Appendix C.

Objective 5: Assess strengths/limitations of approach

In the discussion section each scenario of closed railway crossings within this final matrix is compared and assessed after statistical analysis to see whether there is significance within various closure scenarios. This discussion will also address the accuracy of our model, data biases, and potential impacts on active transportation users.

Results

Walking Analysis

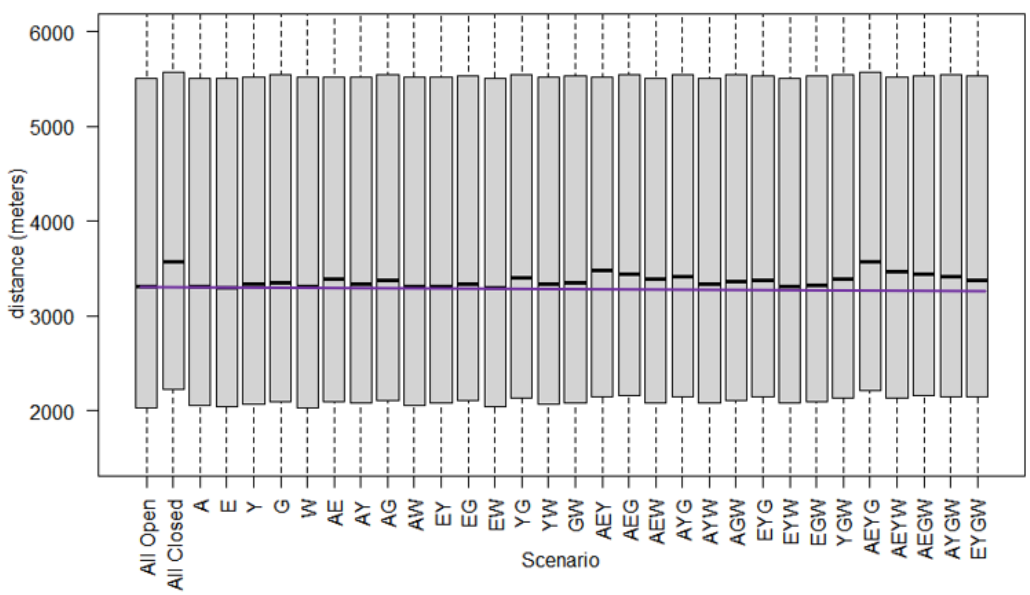

Fig 4: Scaled boxplot showing difference in distance (meters) for all walking scenarios in

relation to the (All Open) crossings control scenario.

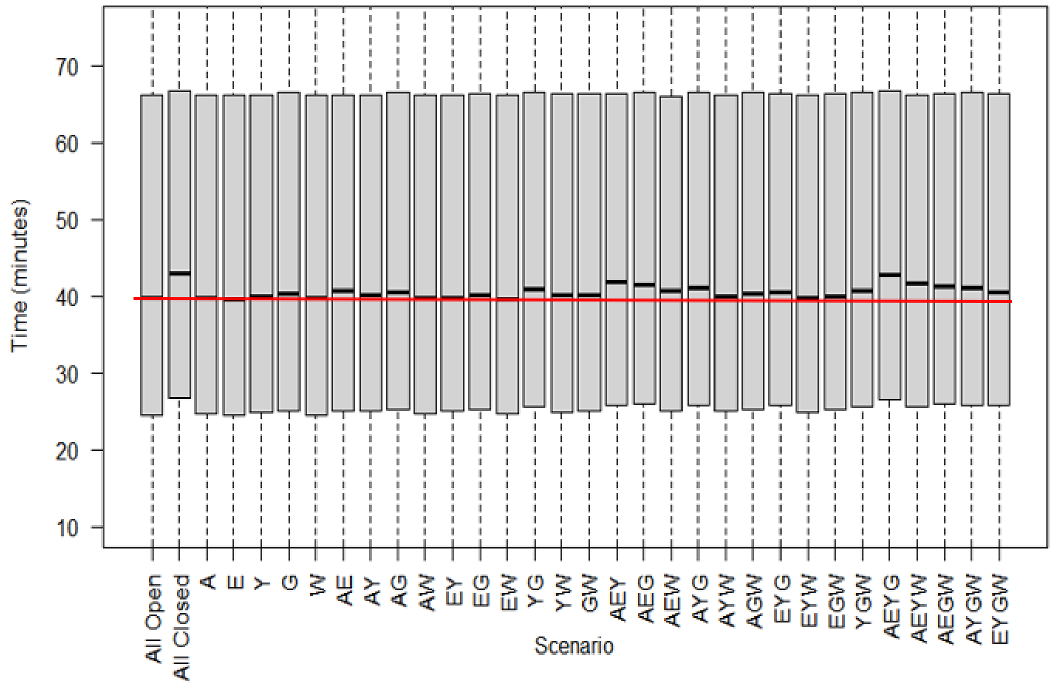

Fig 5: Scaled boxplot showing difference in time (minutes) for all walking scenarios in relation to thel (All Open) crossings control scenario.

Using the paired t-test for walking network data we found that all observed differences in mean length and time between the scenario and control (all crossings open) were significant in rejecting the null hypothesis, that there were no differences from scenario to control (see Appendix A).

The t-tests conducted for the walking scenarios varied in the degrees of freedom (df) with the maximum df value being 144,283 and the minimum df value being 143,564. The mode of df values was 143,564 (n=21), the second most common df value was 143,627 (n=8) (see Appendix A). These variations indicate that not all of the scenarios had the same sample size which should be taken into consideration when viewing the results. We did not perform a test for normativity as our sample sizes were all well above the typical threshold (n> 30) for assuming a normal distribution (Ghasemi & Zahedaisl, 2012).

For the walking scenarios the t-value indicates the magnitude of difference relative to variation within the sample shown in units of standard error. The scenarios which reported the three lowest t-values (less evidence of a significant difference) were the scenarios where only Alma St. crossing closed, where only Edinburgh Rd. crossing closed and where both Edinburgh Rd and Watson Rd had their crossings closed. This is also represented in the mean of differences for both distance and time wherein all reported less than a 10m (<12sec) difference from the all open control scenario. The scenarios which reported the highest t-values (most significant evidence for difference) were the AYG closure, AYGW closure, AEYG closure and the highest was the all crossings closed scenario. These scenarios reported distance and time increases of: 80.76m (57.5 sec), 80.76m (57.5 sec), 133.89m (96 sec) and 135.13m (97.2 sec) respectively (see Appendix A).

Overall the walking scenario which showed the greatest distance and time differences compared to the control was the all crossings closed scenario. The scenario with the lowest difference (<1 m) was the scenario where only Watson Rd. was closed (see Figures 4 & 5). The median mean of the difference value for the walking scenarios was 44.02 meters and 31.69 seconds longer than the control routes. The average mean of differences for the walking scenarios was 49.65m and 35.95 seconds longer than the control routes.

Cycling Analysis

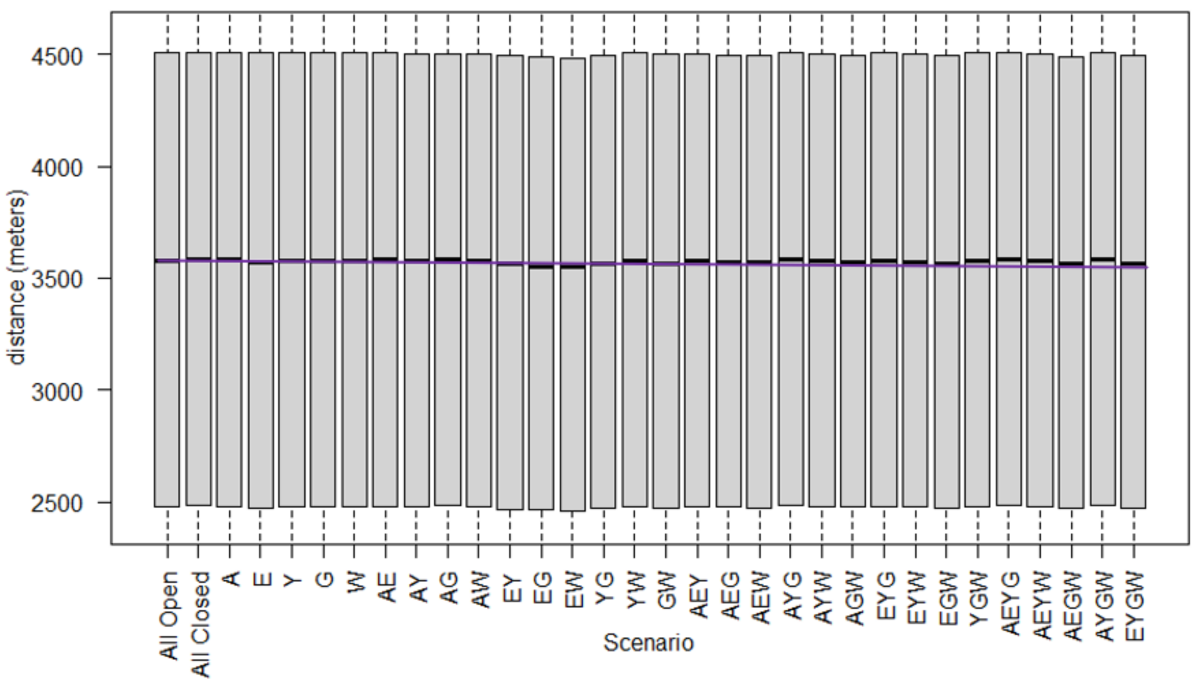

Fig 6: Scaled boxplot showing difference in distance (meters) for all cycling scenarios in relation to the (All Open) crossings control scenario.

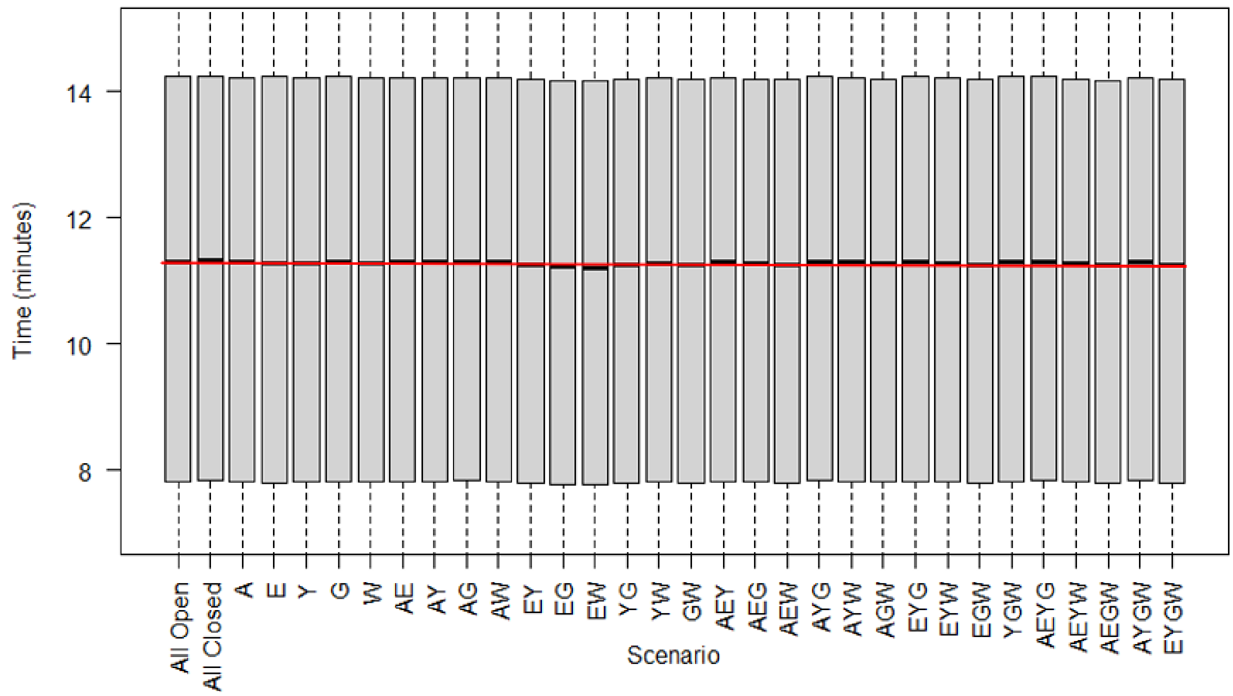

Fig 7: Scaled boxplot showing difference in time (minutes) for all cycling scenarios in relation to the (All Open) crossings control scenario.

Using the paired t-test for cycling network data we found that all observed differences in mean length and time between the scenario and control (all crossings open) were significant in rejecting the null hypothesis, that there were no differences from scenario to control (see Appendix B).

The t-tests conducted for the cycling scenarios varied in the degrees of freedom (df) with the maximum df value being 747,187 and the minimum df value being 734,522. The mode of df values was 741,742 (n=4), (see Appendix B). These variations indicate that the majority of the scenarios had different sample sizes which should be taken into consideration when viewing the results. We did not perform a test for normativity as our sample sizes were all well above the typical threshold (n> 30) for assuming a normal distribution (Ghasemi & Zahedaisl, 2012).

For the cycling scenarios the t-value indicates the magnitude of difference relative to variation within the sample shown in units of standard error. The scenarios which reported the three lowest t-values (less evidence of a significant difference) were the scenarios where only Edinburgh Rd. crossing closed, where only Watson Rd. crossing closed and where both Edinburgh Rd and Watson Rd had their crossings closed. This is also represented in the mean of differences for both distance and time wherein all reported negative differences from the all open control scenario. The scenarios which reported the highest t-values (most significant evidence for difference) were the AYGW closure, AEYG closure and the highest was the all crossings closed scenario. These scenarios reported distance and time increases of: 25.13m (4.76 sec), 25.48m (4.83 sec) and 26.09m (4.94 sec) respectively (see Appendix B).

Overall the cycling scenario which showed the greatest distance and time differences compared to the control was the all crossings closed scenario. The scenario with the lowest difference (faster route than control) was the scenario where only Watson Rd. was closed (see Figures 6 & 7). The median mean of the difference value for the cycling scenarios was 11.86 meters and 2.25 seconds longer than the control routes. The average mean of differences for the walking scenarios was 11.94m and 2.26 seconds longer than the control routes.

Discussion & Limitations

Our outputs highlight what closure scenarios have the greatest impact on active transportation users (see Figures 8 & 9). Additionally as highlighted by Wallace, our model is exploratory in nature; therefore, coefficients and mapped parameter estimates should not be interpreted as predictions (Wallace 2014).

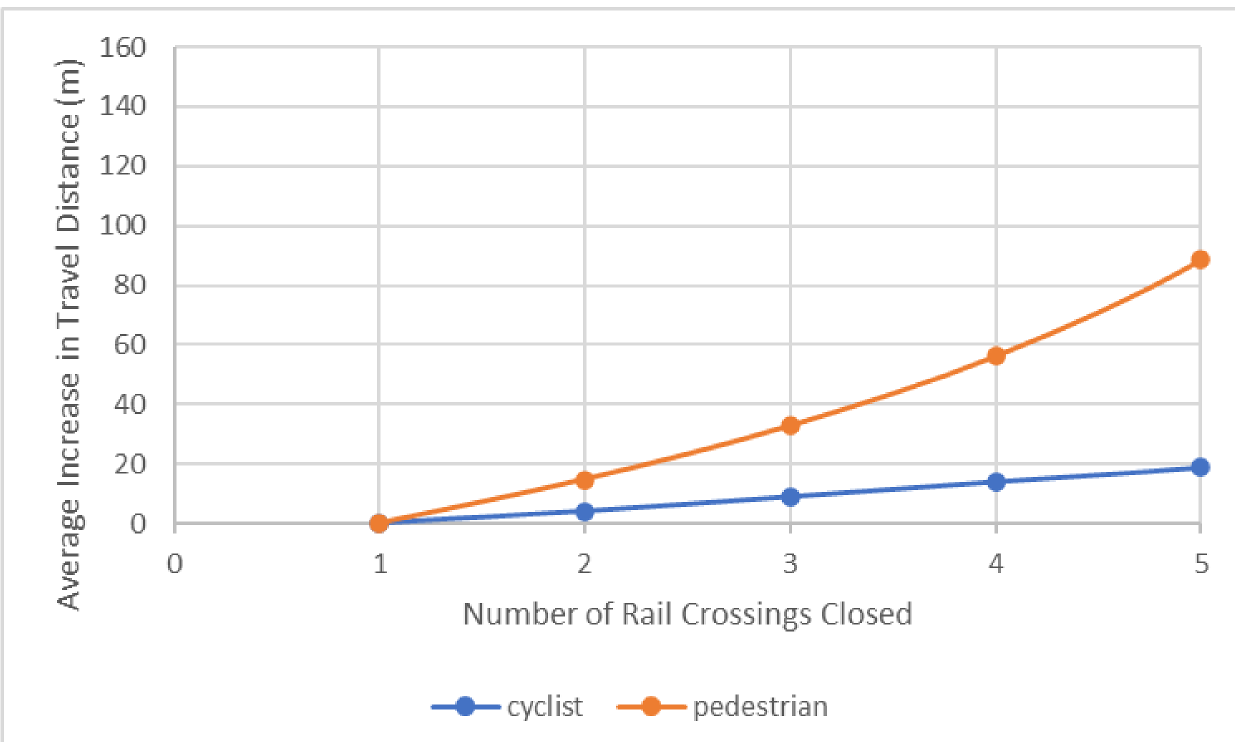

Fig 8. Scatterplot modeling the relationship between the number of crossings closed in a scenario and the average increase in travel distance (m) for cycling and walking AT users.

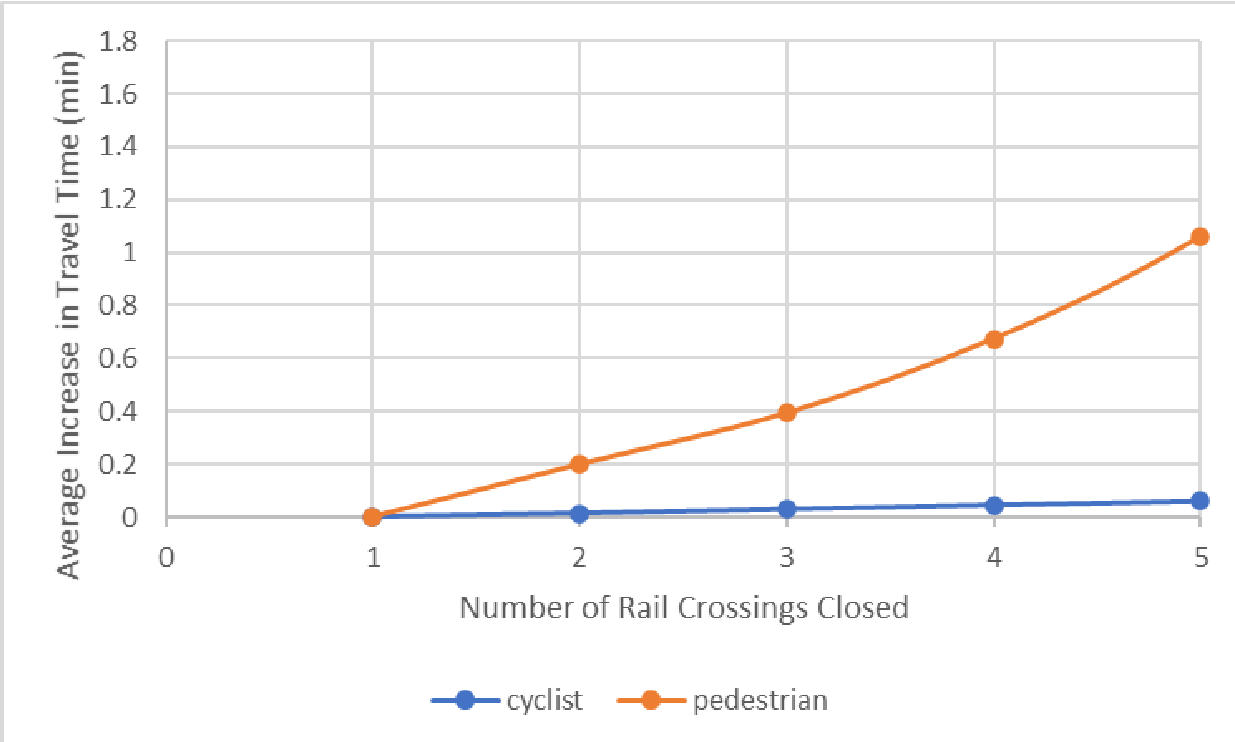

Fig 9. Scatterplot modeling the relationship between the number of crossings closed in a scenario and the average increase in travel time (min) for cycling and walking AT users.

Three main limitations were identified within our study: model limitations, slope, and data quality. When addressing the limitations of our model, assessing the analysis limitations of travel times and distances is essential. ArcPro Network Analyst travel times/distances are estimated so, these methods can be valuable for informing a host of decisions [...]. However, they should be employed with sensitivity to their limitations. (Wallace 2014) For example, within our analysis we were not able to force routes to only use the crossings of interest so the averages may appear lower due to routes that experienced no change since they did not interact with the rail crossings of interest. A further limitation within our analysis is slope. The Slope field was calculated based on the average of points at every quarter of the line segments. It is possible that there were hills in between those points that were missed. Additionally, different segments would have a more or less precise slope depending on the length of that specific segment. Finally, road surface conditions and hazards are not accounted for in our model. There is a lack of data aside from self reported road hazards. As Hardinghaus (2021) highlights, “cannot integrate all potentially influencing factors due to limitations in data availability.”. This was further shown through low quality cycling data that we encountered. As a result of these limitations, we have created a model that is as complete as possible within the data limitations we identified.

Conclusion

Overall our analysis highlights that closures do have a minimal negative impact on pedestrians and cyclists. For Guelph this indicates that specific closure scenarios should be avoided to avoid possible hindrances to active transportation users. However, closures can feasibly be done without detrimental impact to AT users if deemed necessary for the metrolink line.

Future research could be beneficial in assessing the quality of local data, the nature of active transportation, and the relationship of marginalization and other factors in network use. Inclusion of full AAA criteria would also be beneficial to fully understand the impacts to all types of active transportation users. Additionally, further research integrating collision data into the network analysis restrictions could help identify whether avoiding roads with high volumes of collisions could benefit active transportation users. We suggest further research focused on a more detailed understanding of network restrictions on active transportation users. This research is becoming increasingly important as more and more cities begin investing in sustainable transportation infrastructures as a way to reduce carbon dependencies, provide jobs and get on board with the growing wealth that is the green transportation sector (Gopal & Conde, 2021).

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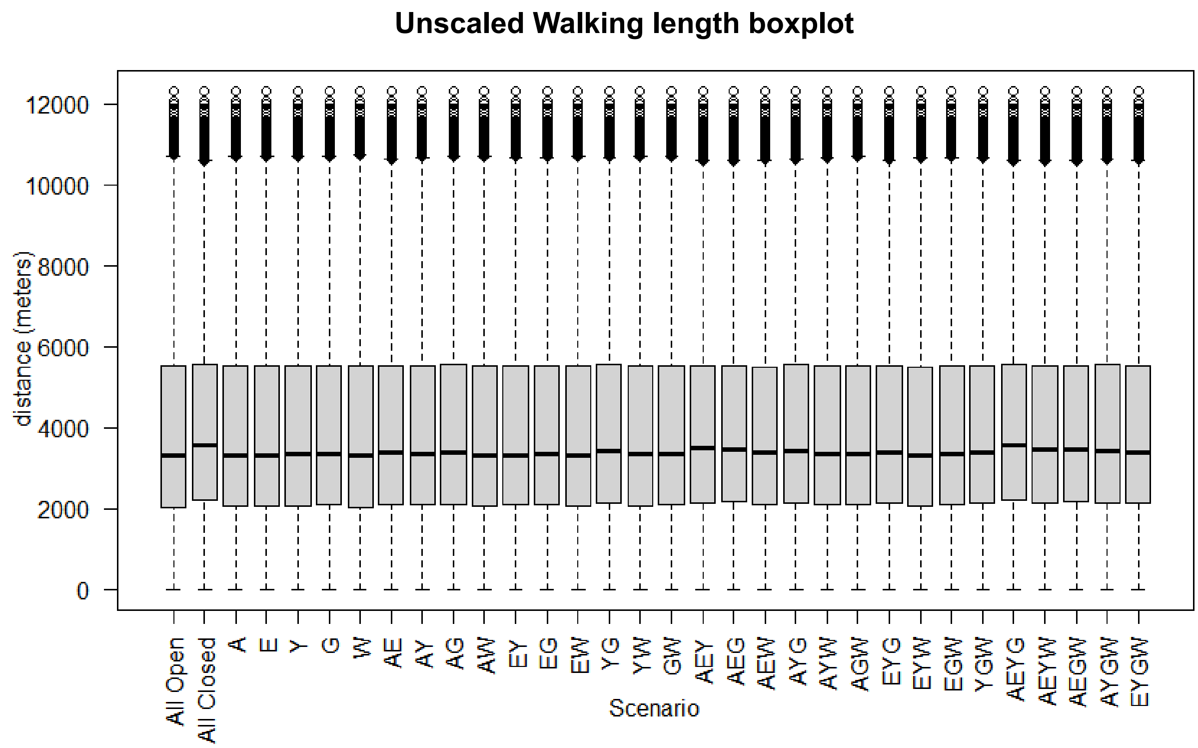
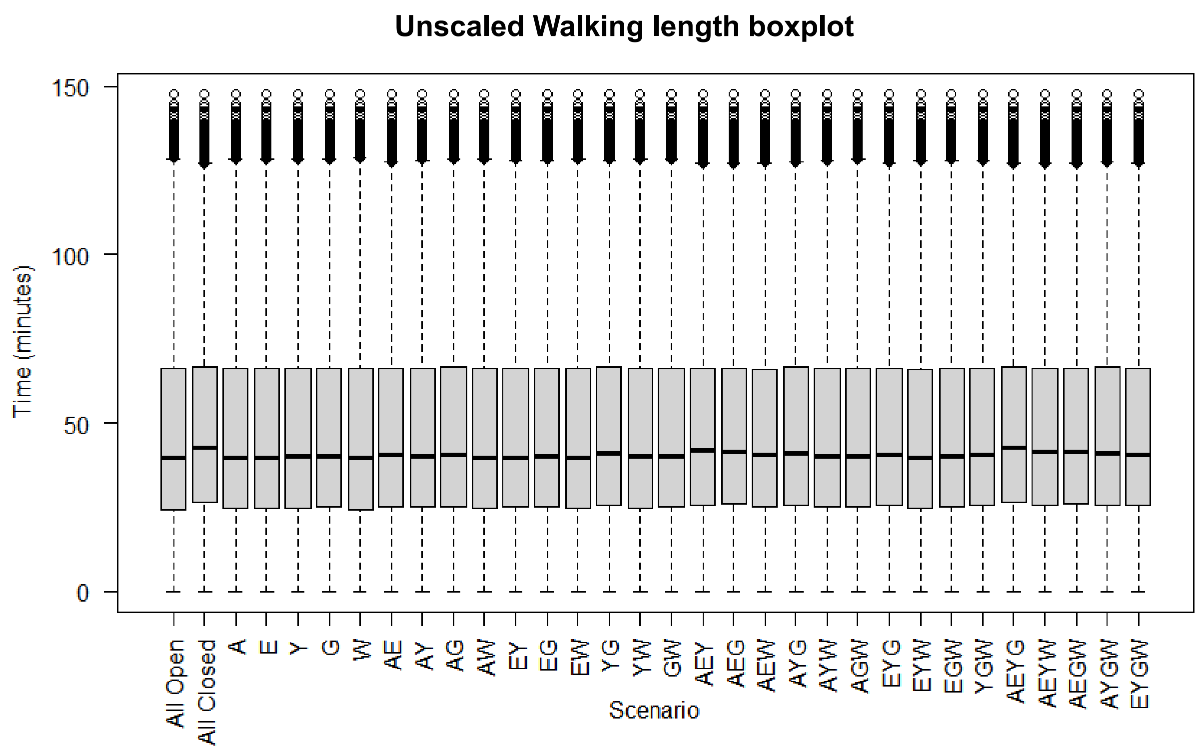
Appendix A: Walking Data Statistical Results

Table 1: T-tests for Walking Length (Distance and Time) Results

SCENARIO	T-VALUE	DEGREES OF FREEDOM	P-VALUE	MEAN OF THE DIFFERENCES (m)	MEAN OF THE DIFFERENCES (min)
Walking_ AllClosed	103.57	144220	0.001	135.1264	1.621517
Walking_A	27.889	144283	0.001	8.356003	0.07698386
Walking_E	23.048	143627	0.001	6.415321	0.2085282
Walking_Y	45.575	143627	0.001	17.37735	0.2085282
Walking_G	72.342	143627	0.001	40.95925	0.491511
Walking_W	6.1127	143564	0.001	0.625148	0.007501775
Walking_AE	50.163	143627	0.001	39.21423	0.4705708
Walking_AY	53.446	143627	0.001	26.47775	0.317733
Walking_AG	88.18	143627	0.001	56.20937	0.6745124
Walking_AW	28.486	143564	0.001	9.037436	0.1084492
Walking_EY	50.537	143627	0.001	23.36745	0.2804094
Walking_EG	73.115	143627	0.001	44.01794	0.5282153
Walking_EW	23.049	143564	0.001	6.41848	0.07702176
Walking_YG	88.787	143564	0.001	64.41902	0.7730282
Walking_YW	45.576	143564	0.001	17.38532	0.2086238
Walking_GW	72.343	143564	0.001	40.97757	0.4917308
Walking_AEY	69.669	143564	0.001	75.87685	0.9105222
Walking_AEG	89.792	143564	0.001	82.15404	0.9858485
Walking_AEW	50.163	143564	0.001	39.23179	0.4707814
Walking_AYG	102.1	143564	0.001	80.76205	0.9691446
Walking_AYW	53.447	143564	0.001	26.48971	0.3178765

Walking_AGW	88.181	143564	0.001	56.23438	0.6748125
Walking_EYG	90.138	143564	0.001	67.98697	0.8158437
Walking_EYW	50.538	143564	0.001	23.37805	0.2805365
Walking_EGW	73.116	143564	0.001	44.0376	0.5284512
Walking_YGW	88.787	143564	0.001	64.41902	0.7730282
Walking_AEYG	102.72	143564	0.001	133.8851	1.606621
Walking_AEYW	69.982	143564	0.001	76.53333	0.9183999
Walking_AEGW	90.048	143564	0.001	82.89658	0.994759
Walking_AYGW	102.1	143564	0.001	80.76205	0.9691446
Walking_EYGW	90.138	143564	0.001	67.98697	0.8158437


Unscaled Walking length boxplot
distance (meters)
0
2000
4000
6000
8000
10000
12000
All Open
All Closed
A
E
Y
G
W
AE
AY
AG
AW
EY
EG
EW
YG
YW
GW
AEY
AEG
AEW
AYG
AYW
AGW
EYG
EYW
EGW
YGW
AEYG
AEYW
AEGW
AYGW
EYGW
Scenario


Unscaled Walking length boxplot
Time (minutes)
0
50
100
150
All Open
All Closed
A
E
Y
G
W
AE
AY
AG
AW
EY
EG
EW
YG
YW
GW
AEY
AEG
AEW
AYG
AYW
AGW
EYG
EYW
EGW
YGW
AEYG
AEYW
AEGW
AYGW
EYGW
Scenario

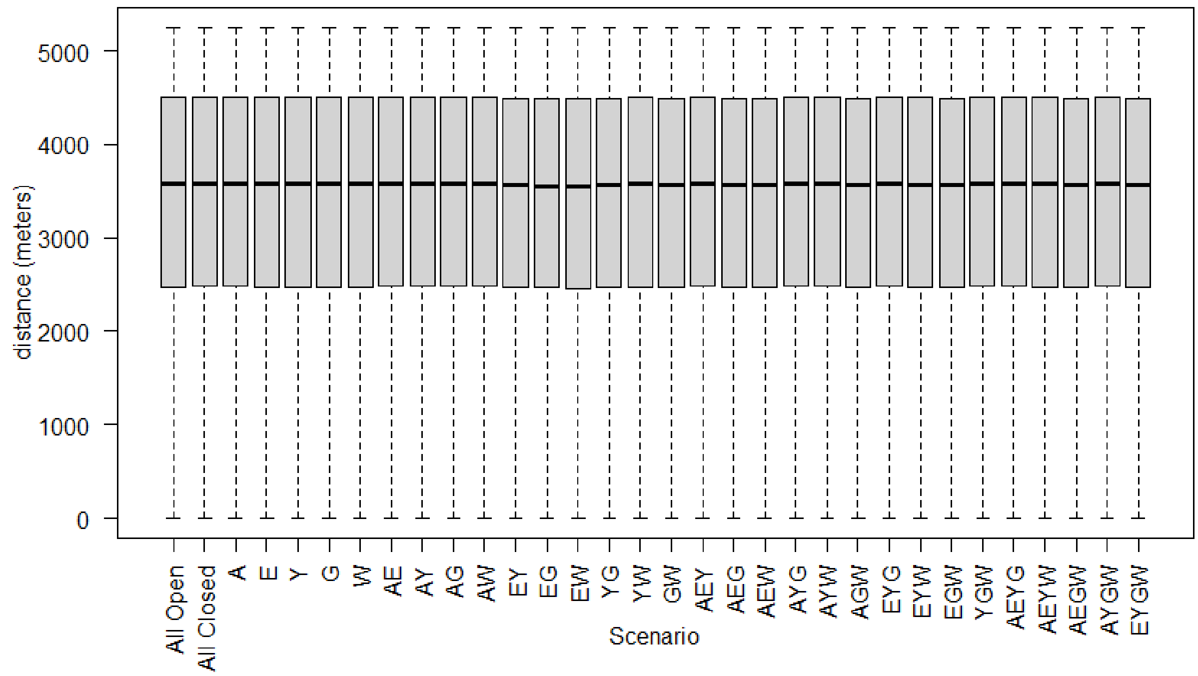
Appendix B: Cycling Data Statistical Results

Table 1: T-tests for Cycling Length (Distance and Time) Results

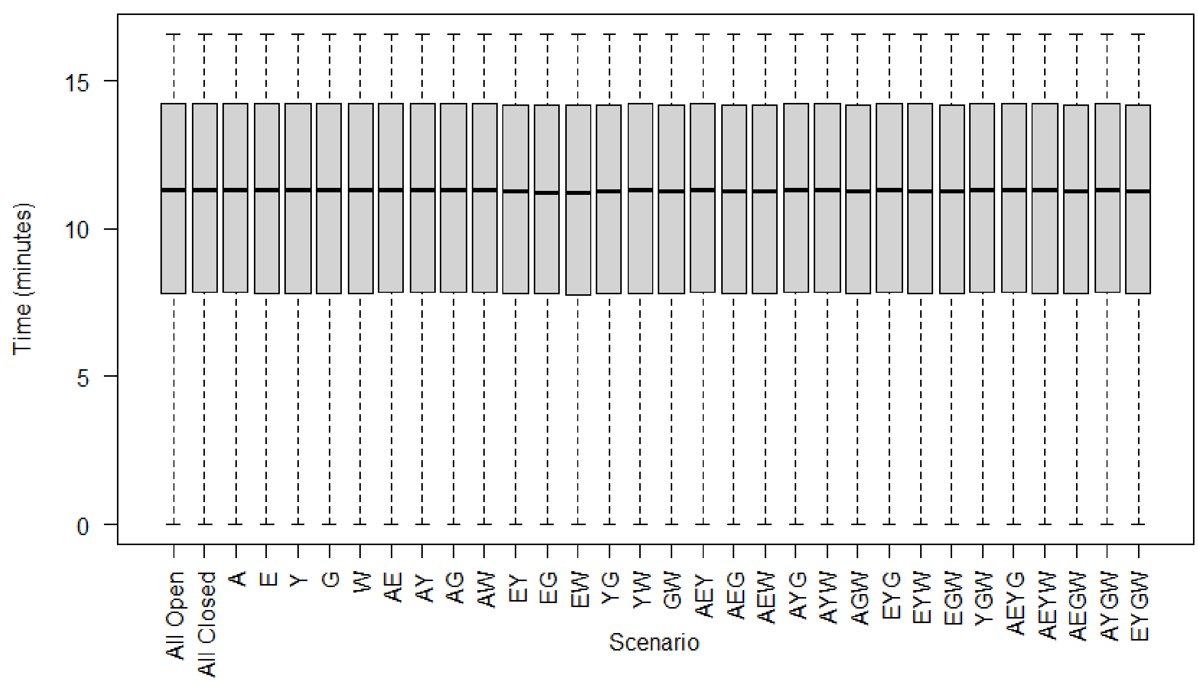
SCENARIO	T-VALUE	DEGREES OF FREEDOM	P-VALUE	MEAN OF THE DIFFERENCES (m)	MEAN OF THE DIFFERENCES (min)
Cycling_ AllClosed	114.32	737815	0.001	26.08624	0.0823776
Cycling_A	75.284	745623	0.001	10.86999	0.03432629
Cycling_E	-13.352	747187	0.001	-0.8114752	-0.002562554
Cycling_Y	54.772	743281	0.001	6.708762	0.02118556
Cycling_G	37.409	746059	0.001	3.874467	0.01223516
Cycling_W	-4.497	747111	0.001	-0.3200223	-0.001010597
Cycling_AE	75.284	745623	0.001	10.86999	0.03432629
Cycling_AY	90.36	736339	0.001	18.89861	0.05967981
Cycling_AG	83.842	741031	0.001	15.16103	0.04787692
Cycling_AW	65.196	742256	0.001	10.51913	0.03321831
Cycling_EY	54.778	738426	0.001	6.753529	0.02132693
Cycling_EG	37.429	737298	0.001	3.922548	0.01238699
Cycling_EW	-4.4687	738350	0.001	-0.3217804	-0.001016149
Cycling_YG	77.521	736963	0.001	11.93936	0.03771325
Cycling_YW	56.285	743205	0.001	7.203567	0.0227481
Cycling_GW	39.72	742007	0.001	4.391501	0.0138679
Cycling_AEY	90.361	736263	0.001	18.90067	0.0596831
Cycling_AEG	83.868	737052	0.001	15.25349	0.04816891
Cycling_AEW	65.206	738350	0.001	10.57616	0.0333984
Cycling_AYG	105.63	734524	0.001	24.62261	0.0777556
Cycling_AYW	91.312	736263	0.001	19.39934	0.06126106

Cycling_AGW	84.833	737049	0.001	15.74256	0.04971336
Cycling_EYG	77.516	741742	0.001	11.86189	0.0374586
Cycling_EYW	56.154	741742	0.001	7.198491	0.02273208
Cycling_EGW	36.855	741742	0.001	3.94683	0.01246367
Cycling_YGW	78.483	741742	0.001	12.35688	0.03902172
Cycling_AEYG	113.33	734531	0.001	25.47706	0.08045386
Cycling_AEYW	90.555	734522	0.001	19.00682	0.06002155
Cycling_AEGW	74.677	734531	0.001	12.52991	0.03956813
Cycling_AYGW	106.44	734525	0.001	25.1289	0.07935442
Cycling_EYGW	78.041	734531	0.001	12.3664	0.03905179

Unscaled Cycling length boxplot



Unscaled Cycling Time boxplot



Appendix C: Links to Raw Data

Compiled Cycling Matrix: Cycling_Matrix_Complete.xlsx

Compiled Walking Matrix: Walking_Matrix_Complete.xlsx