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Proposed Network Reconfiguration for Hamilton Street Railway (HSR)

December 2022

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Report 10

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December 2022

This report is submitted to the City of Hamilton, Department of Public Works, Hamilton Street Railway (HSR) as partial fulfilment of the "A Systemic Assessment and Optimization of Hamilton Street Railway (HSR) Network" research project.

It should be noted that the views expressed in this document are those of the authors and do not necessarily reflect the views of the City of Hamilton.

It should be noted that technical, academic, and statistical phrases are detailed in blue paragraphs to ease the readability of the report. Furthermore, the full results of the statistical analyses are described in the appendix report.

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Executive Summary

In April 2018, the City of Hamilton, public transit division, initiated "*A Systemic Assessment and Optimization of Hamilton Street Railway (HSR) Network*" research project in a partnership with McMaster University.

The research team at McMaster has investigated, quantified, and further evaluated the HSR service across various domains including, perceived quality, desired quality, preferences, attitude, and the willingness to pay of Hamiltonians towards the HSR service. As well as stop utilization, on-time performance, reliability, and the frequencies of the existing HSR operation. Further, the travel behaviour of Hamiltonians is assessed. The research outcomes of these stages were disseminated in several peer-reviewed research papers and nine technical reports submitted to HSR.

These models were deliberated and discussed with the HSR planning team through 22 workshops to inform the proposed reconfiguration of the HSR service. And based on the integration of all these models, the proposed HSR network reconfiguration is guided by achieving eight objectives to facilitate seamless transit travel for all Hamiltonians.

These objectives are implemented to enable direct trips between eight HSR transit hubs ***(Hub-to-Hub No-Transfer Service),*** and to minimize the number of transfers while travelling to/from destinations ***(Hub-to-Origin/Designation One-Transfer Service).*** In addition, the proposed reconfiguration is grounded on the provision of fast, frequent, and reliable services through ***(Higher-Order Fast-Frequent Transit Service).*** The higher-order service is established through the integration of two Bus Rapid Transit (BRT) routes and five Express routes. ***(Regional-connectivity)*** to Go Services (Bus and Rail) is established through three dedicated regional routes, four express routes (Route King, Route Ring, Route A Line, Route Centennial), and 12 collector routes (Route Main East, Route Barton, Route Dundas/Meadowlands, Route Fennell/Mohawk-McMaster, Route Main West, Route U Garth, Route Lime Ridge/Downtown, Route Meadowlands/Downtown, Route Wellington, Route West 5th, Route Upper Gage, Route Upper Sherman). For local communities in Hamilton, the reconfiguration is guided by enhancing ***(Last-Mile Accessibility All Week).*** This was achieved through the provision of local routes with a minimum of 30 minutes between buses.

However, it should be noted that increasing ridership is also associated with ***(Enhanced & Reliable Level of Service),*** which entails the dire need for continuous service monitoring and assessment (planning & operation). In addition to the spatial configuration of HSR routes, hubs, and stops, the constant performance monitoring is essential to tackle any service disruption and to ensure a ***(Resilient & Robust Network).***

The proposed network exhibits a total of 41 routes classified as follows: 2 BRT, 6 Express, 3 Regional, 16 Collectors, and 15 Local routes. The provision of these routes yielded a 7% increase in the population served within 400 meters buffer. Furthermore, there is an approximately 66% increase in the number of trips on Sundays/Holidays and a 71% increase on Saturdays. On Weekdays, the number of trips increased by 52%. However, such an increased level of service is associated with an approximately $55.8 million increase in the annual operation cost. An annual gross operating increase of $36.5 million was contemplated at the end of implementation of Year 5-10 of the 10-Year Local Transit Strategy. Which indicates that the true additional cost is just $19.3 million greater in annual gross operating than what was contemplated at the completion of the 10-year Local Transit Strategy. Nevertheless, the proposed network offers superior travel time and access to destinations compared to the existing HSR service.

Overall, the implementation of the proposed network reconfiguration is strongly recommended.

Disclaimer

The cost values reported herein are extracted from Remix software. The software provides a relatively accurate approximation of the cost. However, to determine precise costs that are inclusive of all the variables specific to HSR staff and fleet resources, additional and resource demanding run-cutting and scheduling analysis is required. Furthermore, the cost values reported herein are not inclusive of the infrastructure cost of the proposed BRT lines.

Therefore, additional analysis is required to model, fine-tune, optimize and cost the implementation of the proposed network reconfiguration at the micro-level using the HSR's comprehensive transit planning resources and network modelling software (Trapeze).

Lastly, should Hamilton LRT project moves forward, additional analysis must be completed to ensure the integration of the proposed network reconfiguration with the Hamilton LRT project.

CHAPTER 1

INTRODUCTION

1. Introduction

Transportation demand is dynamic in nature. New travel patterns are continually shifting/emerging due to population growth, land-use development, attitudes towards travel modes and transportation demand management (i.e., policies and mobility services that encourage people to adopt sustainable travel behaviour). Consequently, public transit providers are constantly reviewing and adjusting their operation to improve the efficiency of the transit service for existing customers and to maximize opportunities to grow ridership.

In this respect, the City of Hamilton, public transit division, initiated "A Systemic Assessment and Optimization of Hamilton Street Railway (HSR) Network" research project in a partnership with McMaster University. The project is developed to achieve two overarching objectives:

> *To arrive at an understanding of the perceived and desired quality of HSR service from the perspective of a wide range of Hamilton residents, including those who use transit regularly or not at all.*
>
> *To suggest a multi-criteria reconfiguration of HSR service based on the evidence of our data collection and modelling efforts.*

This report aims to address the second objective by utilizing the findings from the perceived desired quality measures and service operation benchmarking to propose a multi-criteria reconfiguration of HSR service. The multi-criteria reconfiguration is set to inform: i) HSR Strategic Planning (network, route, and stop alignment), and ii) Tactical Planning (frequency and timetabling).

The multi-criteria reconfiguration is grounded on an understanding of the topological challenges (e.g., street network and escarpment) associated with providing transit service within the City of Hamilton and Hamiltonians' travel needs and expectations. The network reconfiguration is presented primarily across two dimensions; Spatial that focuses on the layout of the proposed transit network and Temporal that focuses on the level of service, timetables, and service frequency.

In brief, the content of each chapter is summarized as follows:

Chapter Two: HSR Reconfiguration Objectives

- This chapter discusses the reconfiguration objectives, philosophy and the proposed guidelines based on the integration of previous reports and semi-structured workshops with HSR personnel. In addition, the chapter outlines the route classification utilized in the proposed network.

Chapter Three: Network-level Assessment

- This chapter presents a holistic assessment of the proposed network across various aspects. The chapter also discusses how the proposed network achieves the objectives, philosophy, and guidelines derived from the previous modelling efforts.

Chapter Four: Data-driven Reconfiguration Process

- This chapter briefly describes the models developed in Report 1 "*Service Quality and Consumers Preferences for Hamilton Street Railway (HSR)*" and Report 2 "*Benchmarking Service Quality for City of Hamilton Transit Division (HSR)*" and outlines the critical information extracted from these models. Overall, this chapter bridges the findings from user engagement models and service benchmarking assessments to inform the proposed service reconfiguration.

Chapter Five: Route-Level Reconfiguration

- This chapter presents a side-by-side comparison between the existing and proposed routes. A description of each existing/proposed route is communicated to highlight their main features.

Chapter Six: Conclusions

- Merited by the analysis developed throughout the report, Chapter Six provides the concluding remarks. The chapter is developed in a bullet point format to ease the interpretation of the concluding remarks.

CHAPTER 2

HSR RECONFIGURATION OBJECTIVES

2. HSR Reconfiguration Objectives

2.1. Introduction

The overall aim of this project is to increase transit ridership, and hence alleviate traffic congestion, in the City of Hamilton. However, increasing ridership requires a set of targeted service improvements/reconfiguration to steadily establish long-term ridership growth. That said, other policies/decisions outside the transit realm (e.g., Travel Demand Management (TDM) measures, land use development, complete streets, etc.) will indeed have tangible impacts on transit ridership.

This chapter outlines a set of proposed objectives directed at increasing transit ridership. These objectives are informed by the findings from the analytical effort (published in four journal papers, five conference papers, and nine reports). The objectives include:

1) Maximizing service reliability,
2) Minimizing the required number of transfers,
3) Expanding the transit service coverage area (Urban Transit Boundary),
4) Improving transit infrastructure,
5) Improving connectivity to regional transit services
6) Expanding service operation hour during weekends,
7) Enhancing network robustness to provide convenient travel alternatives during anticipated and unexpected service disruptions,

Each of these objectives could be implemented using various tools, and at different levels (e.g., micro, and macro). In Table 2-1, high-level considerations to achieve these objectives have been implemented. That said, this set of considerations is not exhaustive, and additional actions outside the transit domain (e.g., travel demand management, parking) might also contribute to realizing the objective of increasing transit ridership.

Table 2-1: High-level Considerations for HSR service reconfiguration

Historical background:	• Significantly altering existing transit routes might not be desirable, as residents' familiarity with the transit system is a key element of building transit ridership. Hamilton residents are not accustomed to adjusting to major changes to transit service delivery. The HSR's transit network has evolved over decades through network tweaks and incremental changes, including a piecemeal of service extensions resulting from the 2001 Amalgamation. • The ability of the current transit network to provide for the needs of the City of Hamilton is constrained because of service limitations imposed by an area-rating funding methodology.
Route and trip directness:	• The bus network should provide as many direct connections as possible between the transit users' origins and destinations. • Directness might be expressed as the additional mileage incurred by the bus trip compared to the same trip by car or other means of transit.

	• Reducing the number of transfers contributes to increasing trip directness.
Network integration:	• The usefulness of a transit network relies on how all parts of the network work together. • A single bus transit route might be beneficial for some trips; however, the integration between all routes adds more significant benefits to a broader spectrum of trips and hence to the entire transit network. • Many aspects of the City's transportation network, such as road and pedestrian infrastructure, cycling paths, local transit routes, and express transit routes need to be considered. • It is common to evaluate the performance of transit lines independently; however, the performance of each line is also heavily dependent on the lines that connect to it. Therefore, timed, and synchronized transfers between routes have a considerable influence on improving riders' transfer experience.
Access to service:	• Transit networks should be designed to move people and accommodate various travel need through a variety of trip types. This, in turn, increases ridership and supports developing long-term ridership growth. • This means providing an adequate extended transit service on Weekdays and weekends for different trip types and destinations. • And provide adequate service coverage to all Hamiltonians.
Efficiency and productivity:	• For a transit service to be productive, the transit network should be aligned as much as possible with demand by providing suitable service types (i.e., express, collector, or local routes) and frequencies. • Efficient and productive transit service targets the middle ground between under-supply and over-supply.
Partnership and collaboration:	• HSR is committed to work with municipal partners and other stakeholders (e.g., developers, institutions) to ensure the coordination of land use and transit inclusive transportation planning. • This coordination can help to develop transit-oriented communities and developments, which in turn supports and sustain an efficient and productive transit network. • Transit-oriented developments help people to become less dependent on cars by encouraging development of communities where walking, cycling, and using transit is more efficient and cost effective
Route-specific considerations:	• In the HSR network reconfiguration, the following guidelines were considered in developing transit routes to promote their efficiency and productivity: i. Matches or improves service levels to demand, ii. Strong anchors at both ends of the transit line, iii. Direct and simple to understand and navigate, and iv. Avoids route redundancies, duplications or overlap as much as possible.

2.2. HSR Reconfiguration Philosophy

The reconfiguration philosophy is grounded on the Total-trip concept, which breaks down the commuting trip into macro, meso (i.e., transition between the micro and macro levels), and micro portions. For example, a trip within the same neighbourhood could be seen as a micro trip. While a trip, for instance, between Dundas and Stoney Creek, could be identified as a meso trip. Moreover, regional connectivity could be classified as a macro trip. That said, some commuting trips might exhibit all three portions; micro, meso, and macro, as highlighted in Figure 2-1.

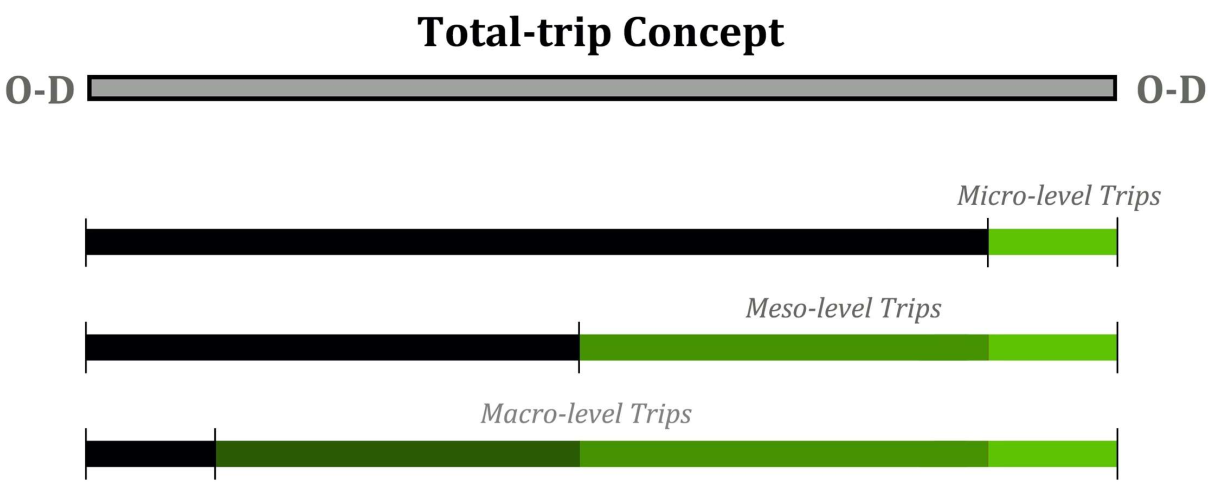


Figure 2-1: Total-trip Concept

In Figure 2-2 and Figure 2-3, the spatial trip context is utilized for conceptualized trip-making within Hamilton. This menu of possibilities can be used to define and manage connectivity within Hamilton and between Hamilton and other trip origins/destinations. Based on this conceptualization, transit routes could be classified into five route types, as follows.

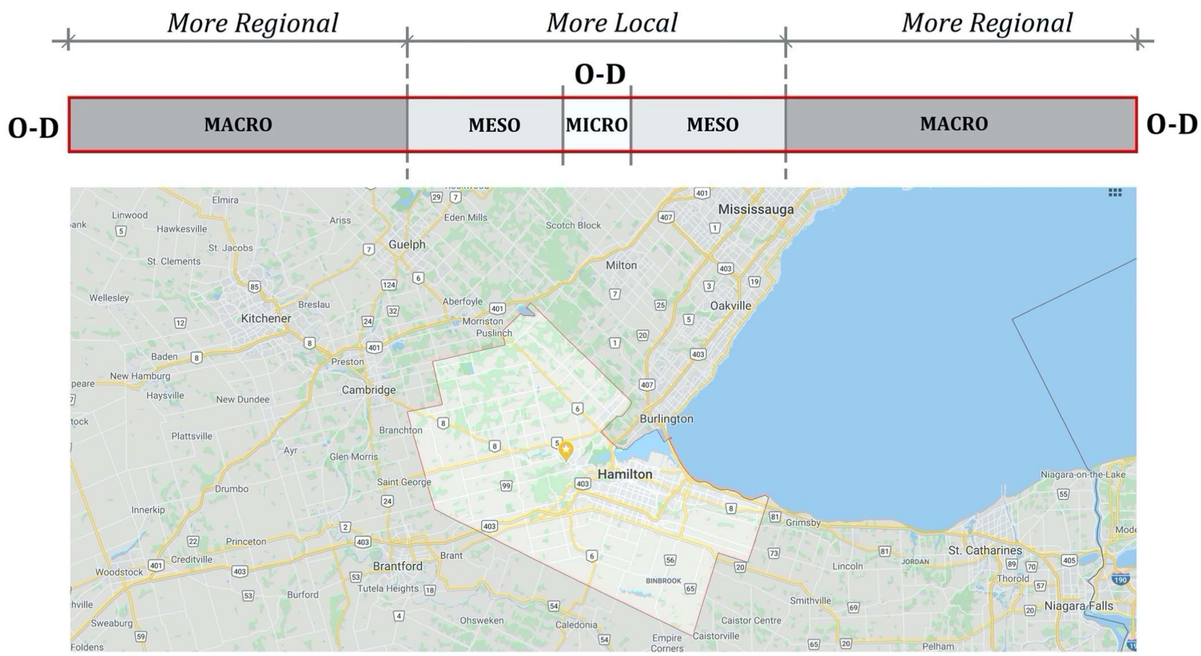


Figure 2-2: Regional & Local Connectivity for Hamilton

Coverage-based Local Routes

These routes provide coverage and accessibility to/from as well as within local neighbourhoods in Hamilton. These are aimed to address the first-last-mile connectivity.

Collector Routes

Collector routes provide options to commute within the city, and target meso-level trips. These routes connect transit hubs, local routes, and major origins/destinations in Hamilton.

Express Routes

Similar to Collector routes, Express routes provide options to commute within the city and target meso-level trips. These routes connect transit hubs, local routes, and major origins/destinations in Hamilton. Further, these routes provide reduced travel time and fewer stops compared to Collectors. The provision of these routes enables HSR to offer fast trips compared to auto travel.

Rapid Higher-Order Routes

With respect to rapid routes, it should be noted that given the uncertainty associated with the provision of Hamilton Light Rail Transit (LRT) in the City of Hamilton during the development of the network reconfiguration report, it is assumed that at the minimum Bus Rapid Transit (BRT) routes will utilize the proposed LRT corridor. This implies that for a large segment of the proposed BRT routes, the service will not operate in mixed-traffic conditions, it will operate in a transit dedicated right of way. This is will indeed enhance service reliability and speed.

Additional information on the provision of rapid transit service in the City of Hamilton is being deliberated by the Hamilton Transportation Task Force. The initial recommendation of the task force (which was announced after the preparation of this report) includes:

"The Task Force's preference is for an intra-city higher-order transit project that addresses the City of Hamilton's transportation needs such as current and future demand and congestion."

Regional Routes

Regional Routes provide connectivity to regional transit services and target meso-level trips. These routes enhance Hamilton connectivity within the Greater Toronto Hamilton Area (GTHA).

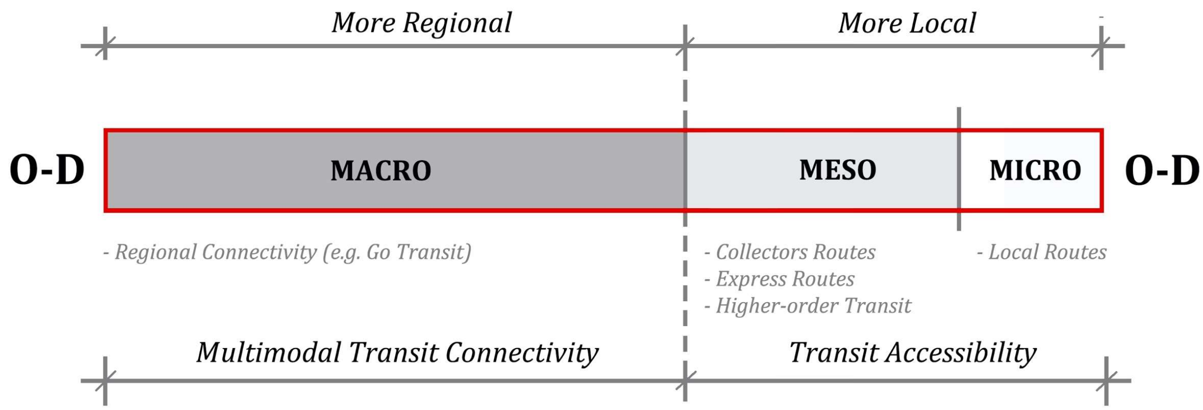


Figure 2-3: Macro, Meso, and Micro routes

These five route types are thought to address and manage the spatial connectivity within Hamilton and between Hamilton and other trip origins/destinations with respect to all trip portions.

2.3. HSR Reconfiguration Guidelines

With an understanding of the objectives and challenges associated with providing transit service to the City of Hamilton, the network reconfiguration was steered by the following spatial and operational guidelines. These guidelines stem from the integration of all the models that were developed by the research team over the last two years and was discussed and revised through numerous workshops with HSR personnel.

Spatial Guidelines

i) Hub-to-Hub No-Transfer Service

- The number of transfers is the most deterring factor of user perceptions towards the quality of HSR service for both current and potential users. Further, from a travel time perspective, direct trips could potentially compete with car travel time. Therefore, the network reconfiguration is developed to achieve direct trips between HSR hubs.

ii) Local-to-Hub No Transfer Service

- All local trips are connected to the nearest hub without any transfer. This will significantly enhance the service connectivity, given that Hub-to-Hub services have direct trips.

iii) Hub-to-Origin/Designation One-Transfer Service

- Similarly, trips to/from any location in the city to a transit hub is constrained to one transfer only. This will contribute to faster and convenient travelling through the city using the HSR service.

iv) Higher-Order Fast-Frequent Transit Service

- Another fundamental issue that emerged through the analysis is the dire need for a fast-frequent service. In this respect, the proposed reconfiguration considers the implementation of higher-order service (e.g., bus rapid transit and express routes).

v) Regional-Connectivity

- The City of Hamilton lies at the heart of the Greater Toronto Hamilton Area (GTHA), and regional connectivity is essential to all Hamiltonians. Therefore, connectivity to regional transit services is emphasized as a crucial building block of the proposed network.

vi) Resilient and Robust Network

- The resilience and robustness of the transit network are a function of the spatial arrangement of routes and stops. Although there is no single solution that contributes to increasing network resilience and robustness, the proposed network reconfiguration is guided by increasing both measures.

Operational Guidelines

vii) First and Last-Mile Accessibility All Week

- First and Last-mile is the Achilles-heel of any transit network. Hamiltonians have also emphasized the enormous benefits of having first and last-mile access on weekends as well as Weekdays. Therefore, the proposed network reconfiguration is based on providing all-week access to local communities. In addition, the proposed network configuration aims to maximize the integration with active travel modes (walking and cycling).

viii) Enhanced & Reliable Level of Service

- From the HSR operation benchmarking analysis, it is apparent that the existing performance measures require some revisions, especially for the time span allocated for on-time performance (two minutes early and five minutes late). Although it is hard to realize this issue through the network reconfiguration, the provision of higher-order transit would contribute to the reliability of the service and would indeed increase the level of service.

ix) Demand-based Stop/Infrastructure Planning

- A predominant message emerged from the analysis is user demand for weather protection at bus stops, coupled with high degree of satisfaction for walking distance to/from stops. Although such indications could not be visualized in the network reconfiguration, a stop rationalization plan for HSR service is strongly recommend. The stop rationalization plan must achieve two overarching objectives. First, stop spacing adjustment based on demand, which in its current form hinders the speed of HSR service. The average spacing between stops in the current HSR service is 297m, which is lower than the standards for City bus service (i.e., 400m in urban, 600m in sub-urban, and 800m in rural areas). Second, there is a demand for more weather protection at bus stops, which should be addressed with respect to the demand at each stop and the potential for required transfer.

In this respect, and through the integration of the proposed route-types and the reconfiguration guidelines, the reconfiguration guidelines are distilled at the route/stop level. First, eight transit hubs are identified in Hamilton (Figure 2-4). The eight hubs represent major attraction/dissemination points across the City of Hamilton and were determined based on: 1) historical ridership data, 2) TTS travel behaviour patterns, and 3) the Ten-Year Local Transit Strategy. These hubs serve as the core structure of the proposed network, and the spatial guidelines are implemented for each hub.

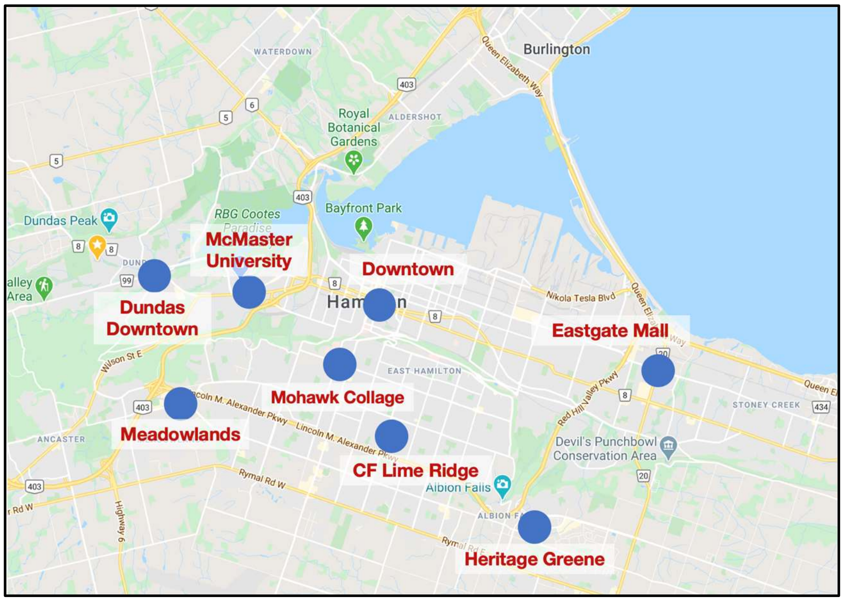


Figure 2-4: Proposed HSR Hubs

Relative to the existing network, the proposed network structure around the eight hubs contributes significantly to increasing network robustness during disruption, which is essential to mitigate any cascading effect resulting from service delay or traffic congestion.

Second, and from an operational perspective, the service will be planned to provide all week operation with varying frequencies depending on route type and the service demand. Except for regional routes, all routes will be developed to feature a minimum frequency of two buses per hour on Sunday. Further, each route type (e.g., collectors, rapid, etc..) will feature unified frequency based on demand and based on route type.

Further, both Local and Collector routes will provide access and coverage for micro- and meso-level trips, respectively. Furthermore, the hub will feature rapid transit and/or express service to enable access to fast, frequent, and reliable services. The hub will also feature access to regional service (e.g., Go Bus and Rail) without any transfers through Regional, Express, or Rapid Transit routes.

CHAPTER 3

NETWORK-LEVEL ASSESSMENT

3. Network-level Assessment

This chapter provides a network-level assessment to inform the decision-making process with respect to the proposed network reconfiguration. The assessment is made across numerous parameters, including cost, accessibility, travel time, and coverage. The assessment is based on some operation parameters. As recommended by the HSR, a $105 per hour is utilized as an approximation of the hourly service cost, 15% recovery time for schedule and operator needs, 252 Weekdays of operation, 52 Saturdays, and 61 Sundays / Holidays. These parameters are utilized for both the existing and the proposed networks. It should be noted that the HSR annual operation was not fixed, rather the annual cost was estimated from the proposed network.

3.1. Network Operational Cost

In the proposed network, and in reference to the Fall-2019 HSR operating network the total number of annual operating hours will increase by almost 69%, which corresponds to a 74% increase in the annual operating cost and a nearly 41% increase in the number of annual trips. This increase in the number of trips will provide Hamiltonians with more frequent and reliable transit service. It needs to be noted that this increase is inclusive of the operating cost of the proposed BRT, which provides higher-order transit service to Hamiltonians beyond the existing services and has been identified as a key component to the City's growth strategy.

Furthermore, there is a 64% increase in the number of trips on Sundays/Holidays and a 58% increase on Saturdays, while a 36% increase on Weekdays. This matches Hamiltonians' preferences to have more service on weekends and holidays. Table 3-1 presents a comparison between the current and proposed networks based on the main operating costs.

*Table 3-1: Current and proposed networks comparison (based on Remix software) **

	Current Network**	Proposed Network***	Difference Proposed-Current	Percentage increase (difference/current)
Annual Operation				
Annual Cost ($ million)	90.1	156.7	**66.6**	74%
Operating hours per Year (hrs.)	857,636	1,452,007	**594,371**	69%
No. of trips per Year	1,250,167	1,764,900	**514,733**	41%
Fleet Kilometers Travelled per Year	16,118,026	27,549,475	**11,431,449**	71%
No. of routes	34	41	**7**	21%
No. of in-service buses (at peak)	212	279	**67**	32%
Weekday Operation				
Cost per Weekday ($ thousand)	286.6	483.1	**196.5**	69%
Operating hours per Weekday (hrs.)	2,730	4,476	**1,746**	64%
No. of trips per Weekday	3,953	5,358	**1,405**	36%
Fleet Kilometers Travelled per Weekday	50,719	67,257	**16,538**	33%
Saturday Operation				
Cost per Saturday ($ thousand)	188.2	366.8	**178.6**	95%
Operating hours per Saturday (hrs.)	1,792	3,398	**1,606**	90%
No. of trips per Saturday	2,730	4,310	**1,580**	58%
Fleet Kilometers Travelled per Saturday	34,981	67,257	**32,276**	92%
Sunday Operation				
Cost per Sunday ($ thousand)	131.7	260.5	**128.8**	98%
Operating hours per Sunday (hrs.)	1,255	2,414	**1,159**	92%
No. of trips per Sunday	1,903	3,124	**1,221**	64%
Fleet Kilometers Travelled per Sunday	24,884	47,429	**22,545**	91%

** Please note that these values do not reflect the cost and additional kilometer travelled for deadheading.*
*** Current network data is based on the Fall 2019 board period.*
**** It should be noted that the proposed network implements four zones of on-demand transit service: Waterdown, Stoney Creek, Ancaster, and Dundas. The cost associated with these areas are not included in Table 3-1.*

3.2. Demographic Assessment

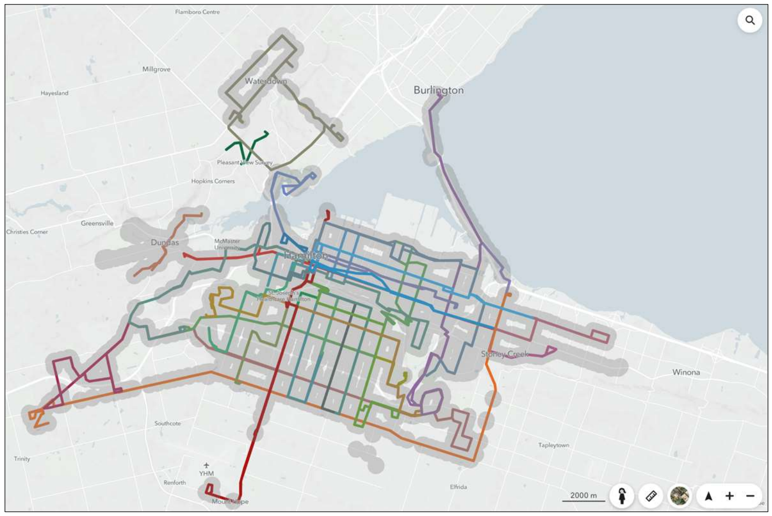
The proposed network exhibits a 14% increase in the population served within a 400-meter buffer and a 10% increase in access for occupied dwellings within the same buffer threshold. In addition, the number of employees within 400 meters increased by 14%. Nonetheless, the percentage of the low-income population within 400 meters buffer almost doubled with an 86% increase. It is worth mentioning that those numbers reflect only static (spatial) network coverage regardless of service operating parameters. In this respect, accessibility to the service (with respect to the frequency of the routes) has enhanced substantially. Table 3-2 shows the coverage of both current and proposed networks for different demographic aspects.

Table 3-2: Current and proposed networks comparison (Demographic-based)

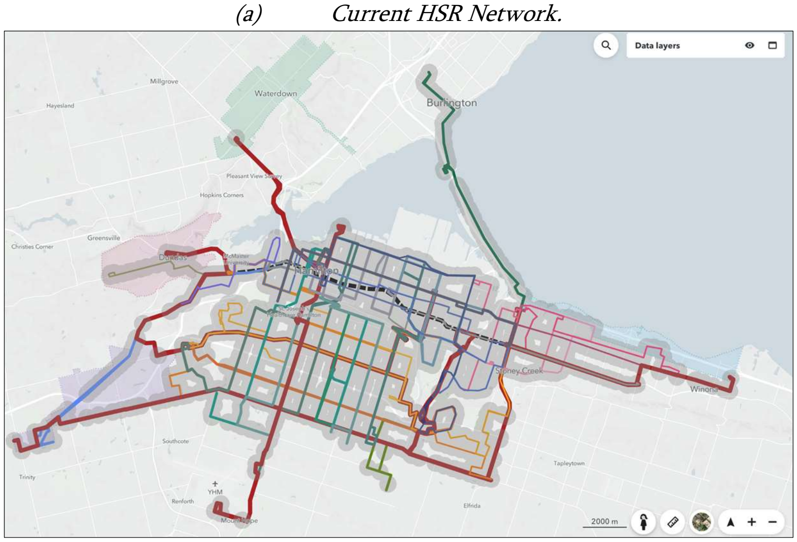
	Current Network	Proposed Network	Difference (Δ)	Percentage increase difference/current
Population served within 400 meters	418,900	477,000	**58,100**	14%
Population served within 600 meters	458,251	514,900	**56,649**	12%
Population served within 800 meters	475,428	541,700	**66,272**	14%
Occupied dwellings within 400 meters	157,500	174,000	**16,500**	10%
Employees within 400 meters	187,700	213,300	**25,600**	14%
Low income within 400 meters	14%	26%	**12%**	86%
Minorities within 400 meters	20%	37%	**17%**	85%
Seniors (65+) within 400 meters	18%	50%	**32%**	178%
Adults (20-64) within 400 meters	61%	73%	**12%**	20%

3.3. Accessibility, Travel Time, and Coverage Assessment

The proposed network offers an 11.89% increase in geographical coverage compared to the current HSR network. The proposed network improves transit geographical accessibility mainly to the Stoney Creek North industrial area, Clappison's Corners retail/commercial uses in Waterdown, and Go rail services. Figure 3-1 shows the proposed versus current network coverage considering 400-meter walking distance to bus stops.



(a) Current HSR Network.



(b) Proposed HSR Network Reconfiguration

Figure 3-1: HSR Coverage Map (Current Network top, Proposed Network bottom)

Furthermore, the proposed network offers unified headways (time between consecutive buses) for each route type. This eases trip planning process for passengers, and enables a seamless integration with the Hamilton LRT operating schedule.

In comparison to coverage and spatial accessibility assessment, a spatiotemporal accessibility measure is more superior in comparing the two networks. As such, an isochrone tool (Jane in Remix Transit Platform) was used to check ***how far transit customers can travel in 15, 30, 45 and 60 minutes*** considering specific origin locations in the current HSR network and compared with the proposed reconfiguration. The travel time is assumed at 10:00 am. Those locations include the proposed HSR eight hubs, Downtown, McMaster University, Eastgate Terminal, Meadowlands Terminal, Mohawk College, CF Lime Ridge Mall, Heritage Greene Terminal, and Dundas downtown.

It should be noted that these comparisons are based on a single point in time (08:00 am). However, the overall network comparison illustrated in Tables 3-1 and 3-2 shows the advantages of the proposed network over the existing HSR network.

Furthermore, the spatial coverage model does not take into consideration the four on-demand areas: Dundas, Ancaster, Stoney Creek, and Waterdown, detailed in Figure 3-2.

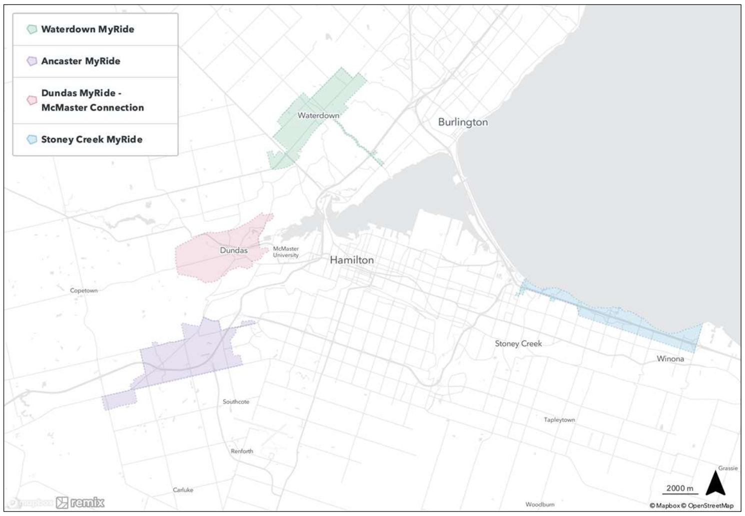
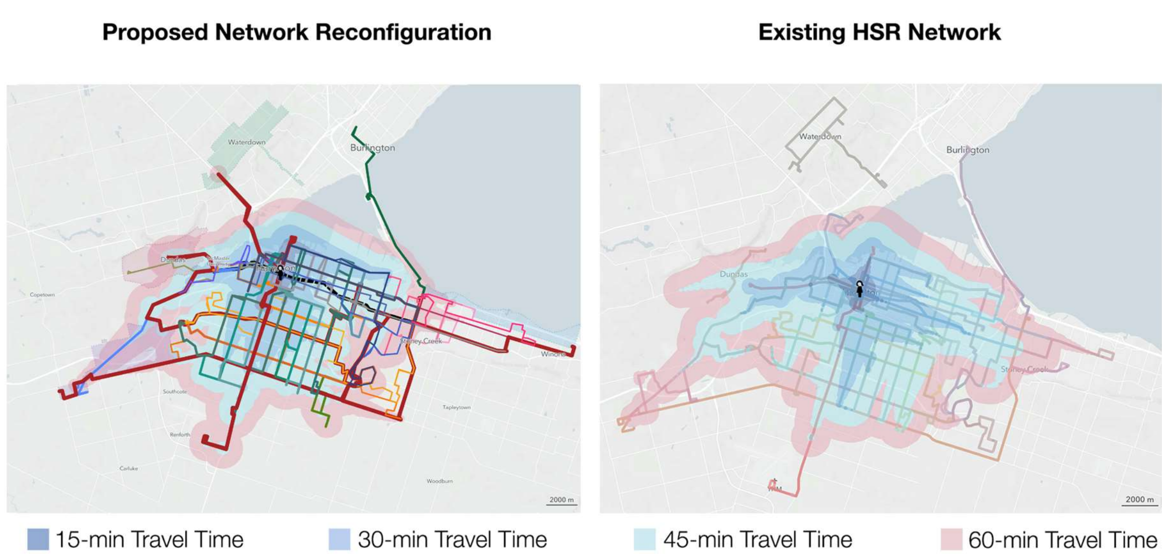


Figure 3-2: Proposed on-demand operation areas.

The generated travel time maps show that the proposed network offers more opportunities (over time and space) to transit users compared to the current network. Hamiltonians can reach more places, opportunities, and activities in the same travel time. It is worth noting that those improvements are more tangible on Saturdays and Sundays. Table 3-3 shows how far transit users can travel in 15, 30, 45, and 60 minutes on a weekday for the current and proposed networks as well as the associated population coverage. In comparison, Table 3-4 and Table 3-5 communicate the same information for Saturday and Sunday, respectively.

Table 3-3: Comparisons between existing and proposed HSR network (08:00 am Weekday)

Downtown

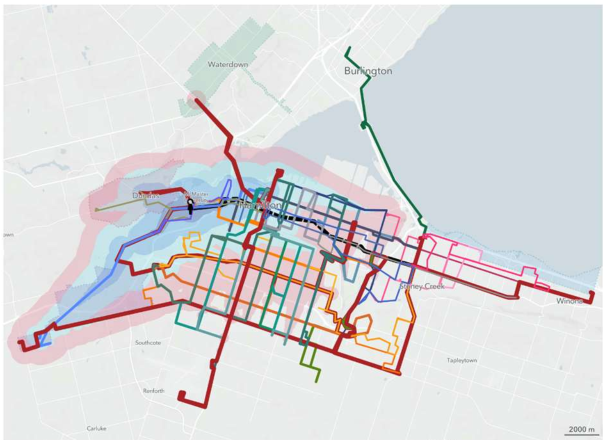


Travel time	Proposed Network		Existing Network		Difference	
	Population	Employed	Population	Employed	Population	Employed
15-min	44,373	19,875	29,590	13,059	14,783	6,816

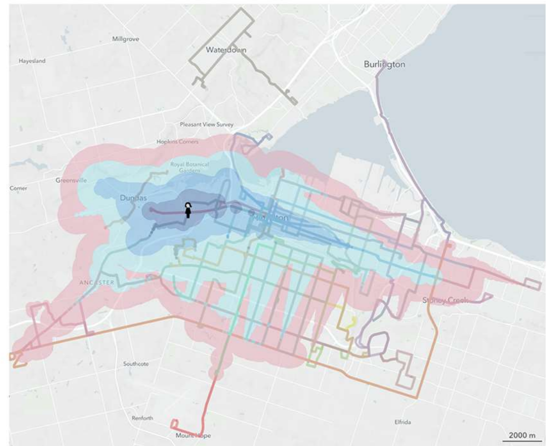
30-min	161,269	70,147	162,274	71,410	-1,005	-1,263
45-min	320,981	140,809	334,151	146,033	-13,170	-5,224
60-min	406,354	179,012	419,574	184,953	-13,220	-5,941

McMaster University

Proposed Network Reconfiguration



Existing HSR Network

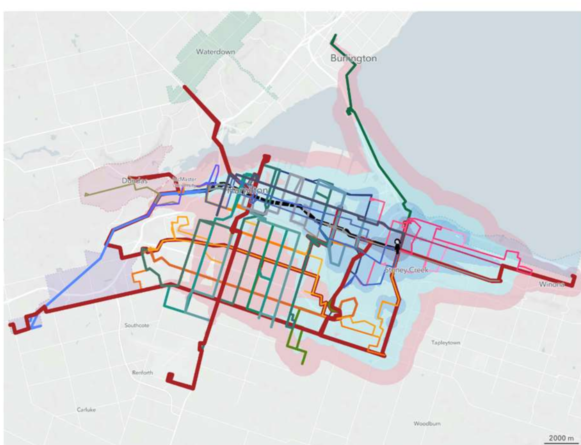


15-min Travel Time 30-min Travel Time 45-min Travel Time 60-min Travel Time

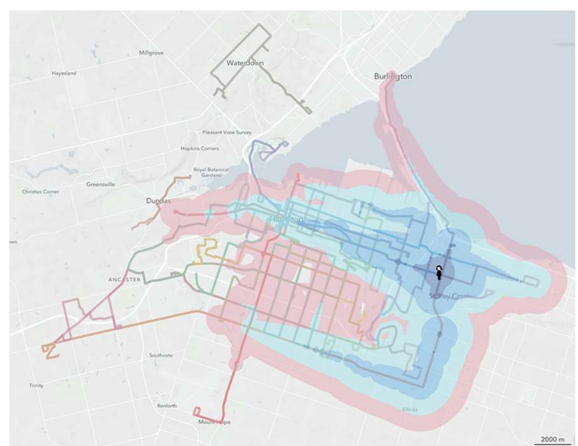
Travel time	Proposed Network		Existing Network		Difference	
	Population	Employed	Population	Employed	Population	Employed
15-min	8,187	3,411	10,896	4,667	-2,709	-1,256
30-min	49,982	21,347	82,828	35,646	-32,846	-14,299
45-min	149,772	64,975	222,351	97,249	-72,579	-32,274
60-min	320,080	141,477	377,895	165,943	-57,815	-24,466

Eastgate Terminal

Proposed Network Reconfiguration



Existing HSR Network



15-min Travel Time 30-min Travel Time 45-min Travel Time 60-min Travel Time

Travel time	Proposed Network		Existing Network		Difference	
	Population	Employed	Population	Employed	Population	Employed
15-min	16,344	6,302	16,232	6,256	112	46
30-min	113,876	49,332	113,349	49,897	527	-565
45-min	245,249	110,242	266,806	118,695	-21,557	-8,453
60-min	384,886	172,083	404,378	179,641	-19,492	-7,558

Meadowlands Terminal

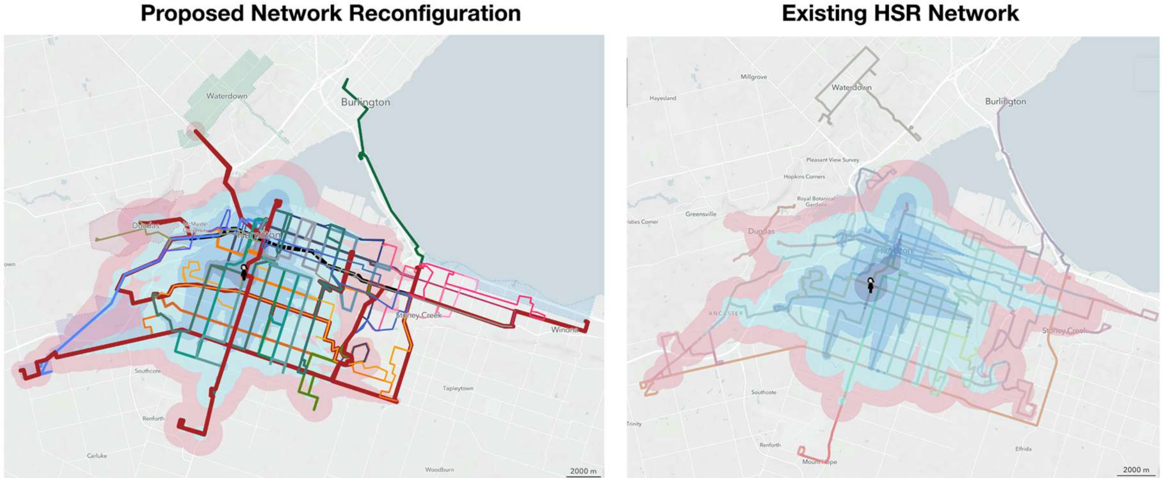
Proposed Network Reconfiguration | **Existing HSR Network**

15-min Travel Time | 30-min Travel Time | 45-min Travel Time | 60-min Travel Time

Travel time	Proposed Network		Existing Network		Difference	
	Population	Employed	Population	Employed	Population	Employed
15-min	10,422	4,239	12,616	5,052	-2,194	-813
30-min	90,896	40,050	77,403	33,830	21,493	6,220
45-min	267,590	118,363	219,262	97,773	48,328	20,590
60-min	348,653	154,758	351,379	156,050	-2,726	-1,292

Mohawk College

Proposed Network Reconfiguration | **Existing HSR Network**

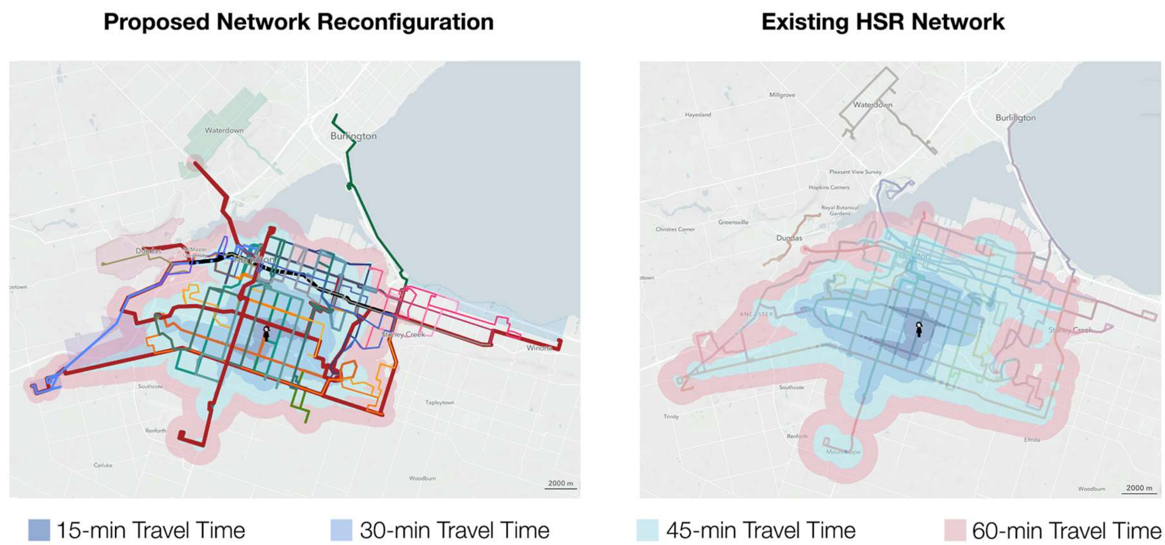


15-min Travel Time | 30-min Travel Time | 45-min Travel Time | 60-min Travel Time

Travel time	Proposed Network		Existing Network		Difference	
	Population	Employed	Population	Employed	Population	Employed
15-min	27,211	12,359	23,132	10,414	4,079	1,945

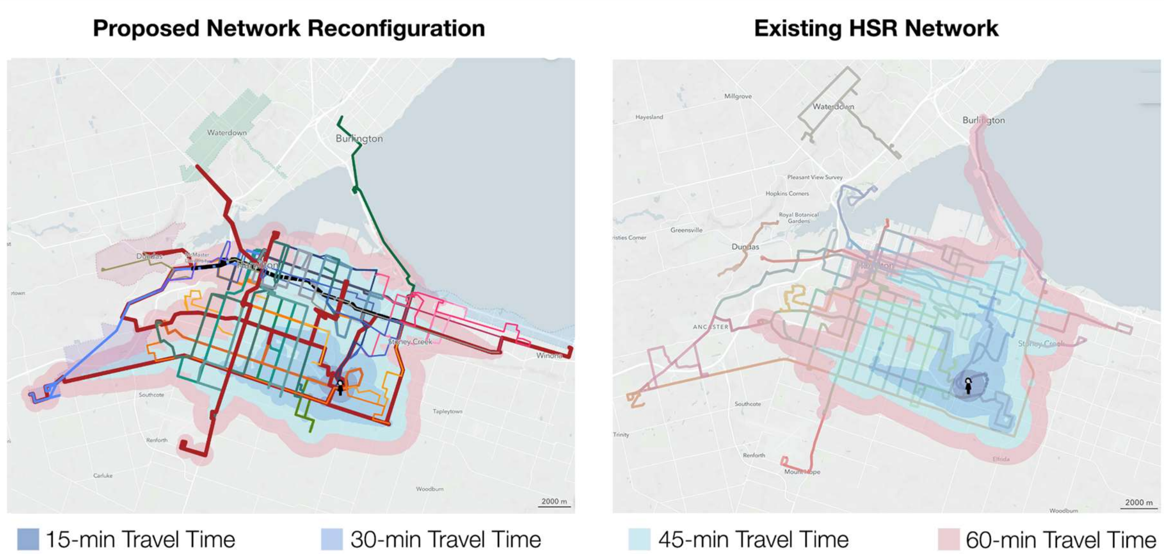
30-min	173,441	75,879	71,733	75,493	101,708	386
45-min	305,141	134,101	332,406	146,592	-27,265	-12,491
60-min	378,314	167,575	415,115	183,446	-36,801	-15,871

CF Lime Ridge Mall



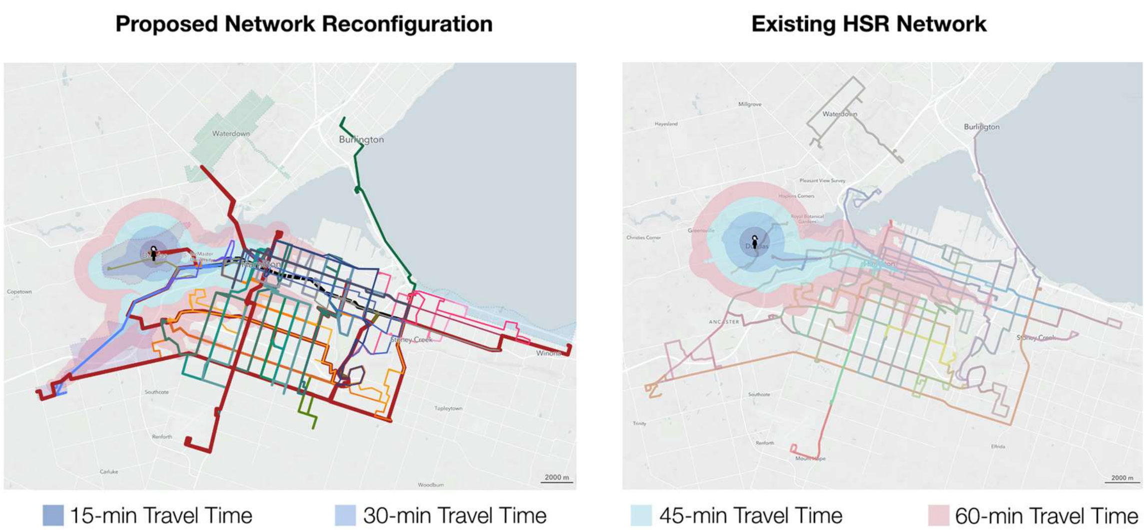
Travel time	Proposed Network		Existing Network		Difference	
	Population	Employed	Population	Employed	Population	Employed
15-min	21,204	9,066	21,119	9,448	85	-382
30-min	139,359	63,650	161,097	71,643	-21,738	-7,993
45-min	285,131	126,977	319,880	142,050	-34,749	-15,073
60-min	360,980	161,341	418,510	185,292	-57,530	-23,951

Heritage Greene Terminal



Travel time	Proposed Network		Existing Network		Difference	
	Population	Employed	Population	Employed	Population	Employed
15-min	5,865	2,846	5,460	2,748	405	98
30-min	109,930	50,942	65,475	30,433	44,455	20,509
45-min	304,024	134,825	239,020	107,440	65,004	27,385
60-min	508,781	181,855	376,625	167,133	132,156	14,722

Dundas Downtown

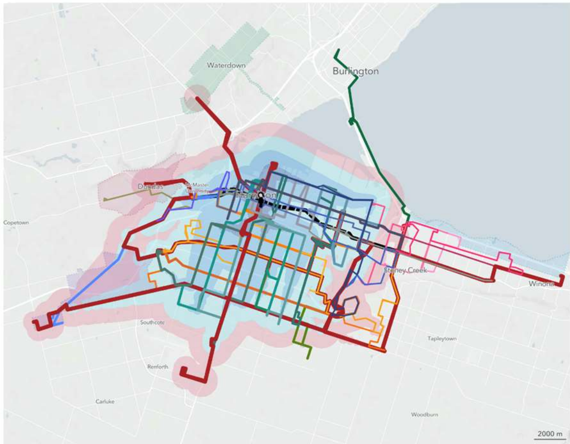


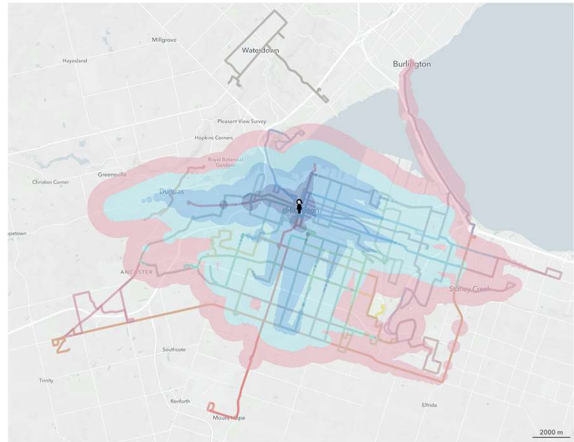
Travel time	Proposed Network		Existing Network		Difference	
	Population	Employed	Population	Employed	Population	Employed
15-min	6,614	2,506	9,462	3,915	-2,848	-1,409
30-min	25,296	10,794	36,118	15,511	-10,822	-4,717
45-min	67,265	29,358	112,218	49,086	-44,953	-19,728
60-min	164,729	72,811	279,977	123,585	-115,248	-50,774

Table 3-4: Comparisons between existing and proposed HSR network (08:00 Saturday)

Downtown

Proposed Network Reconfiguration | **Existing HSR Network**



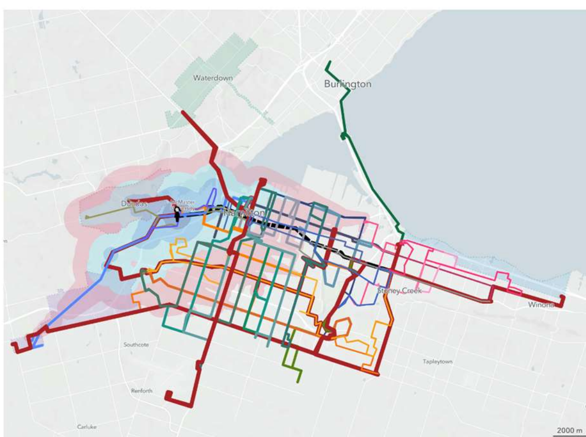


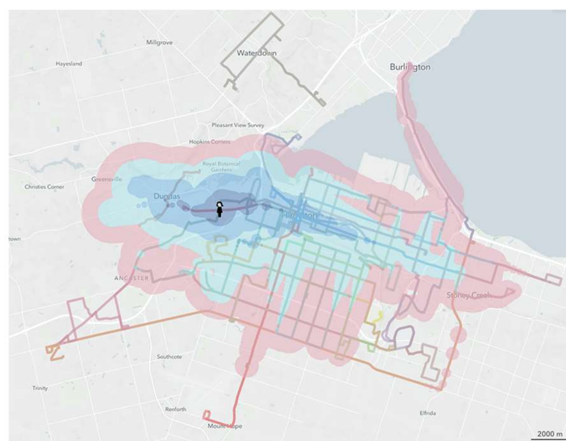
15-min Travel Time | 30-min Travel Time | 45-min Travel Time | 60-min Travel Time

Travel time	Proposed Network		Existing Network		Difference	
	Population	Employed	Population	Employed	Population	Employed
15-min	41,080	18,162	21,496	9,436	19,584	8,726
30-min	194,305	85,063	116,890	50,816	77,415	34,247
45-min	328,239	145,054	292,822	128,481	35,417	16,573
60-min	392,544	173,364	392,305	172,062	239	1,302

McMaster University

Proposed Network Reconfiguration | **Existing HSR Network**



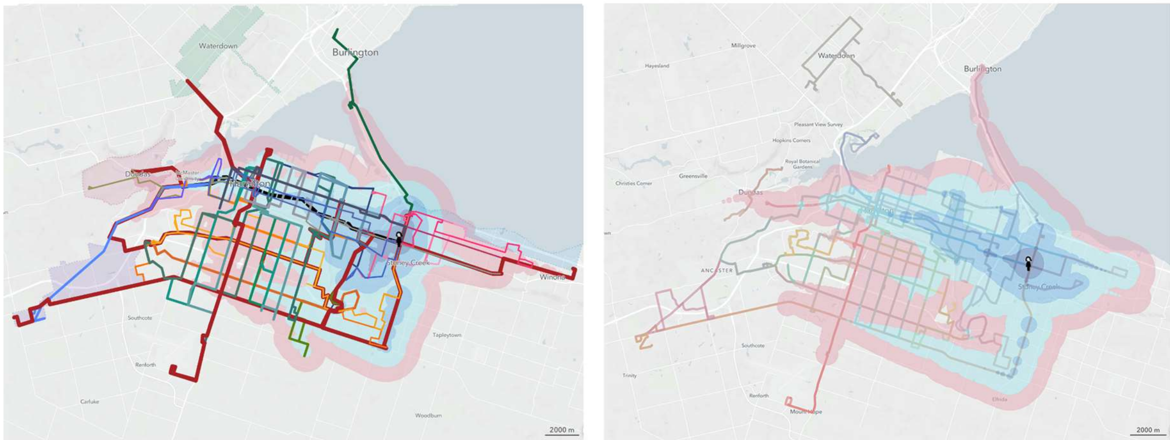


15-min Travel Time | 30-min Travel Time | 45-min Travel Time | 60-min Travel Time

Travel time	Proposed Network		Existing Network		Difference	
	Population	Employed	Population	Employed	Population	Employed
15-min	3,155	1,251	13,285	5,429	-10,130	-4,178
30-min	26,504	11,229	69,842	30,480	-43,338	-19,251
45-min	108,691	47,261	190,843	83,531	-82,152	-36,270
60-min	242,733	106,071	337,082	148,275	-94,349	-42,204

Eastgate Terminal

Proposed Network Reconfiguration | **Existing HSR Network**

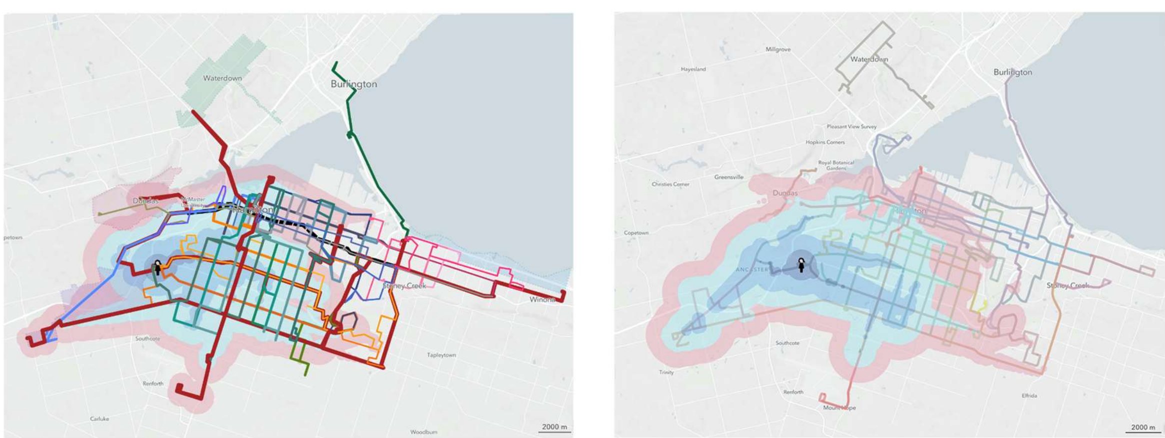


15-min Travel Time | 30-min Travel Time | 45-min Travel Time | 60-min Travel Time

Travel time	Proposed Network		Existing Network		Difference	
	Population	Employed	Population	Employed	Population	Employed
15-min	20,228	7,940	9,803	3,600	10,425	4,340
30-min	98,242	42,341	76,468	32,698	21,774	9,643
45-min	245,127	107,949	198,814	87,208	46,313	20,741
60-min	368,383	164,527	356,389	158,558	11,994	5,969

Meadowlands Terminal

Proposed Network Reconfiguration | **Existing HSR Network**



15-min Travel Time | 30-min Travel Time | 45-min Travel Time | 60-min Travel Time

Travel time	Proposed Network		Existing Network		Difference	
	Population	Employed	Population	Employed	Population	Employed
15-min	9,589	3,859	14,479	5,874	-4,890	-2,015
30-min	93,265	41,115	84,188	37,019	9,077	4,096

45-min	241,046	107,132	189,102	84,542	51,944	22,590
60-min	331,371	146,487	348,452	154,294	-17,081	-7,807

Mohawk College

Proposed Network Reconfiguration | **Existing HSR Network**

Travel time	Proposed Network		Existing Network		Difference	
	Population	Employed	Population	Employed	Population	Employed
15-min	24,593	10,879	17,793	8,093	6,800	2,786
30-min	182,471	80,381	145,856	63,855	36,615	16,526
45-min	317,080	140,547	311,318	136,861	5,762	3,686
60-min	380,307	167,996	394,455	173,096	-14,148	-5,100

CF Lime Ridge Mall

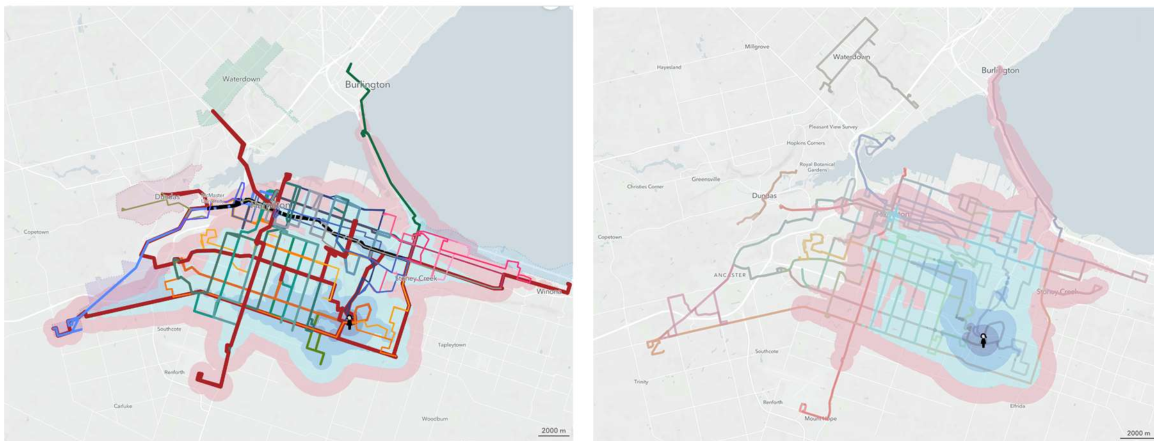
Proposed Network Reconfiguration | **Existing HSR Network**

Travel time	Proposed Network		Existing Network		Difference	
	Population	Employed	Population	Employed	Population	Employed

15-min	21,784	9,649	16,900	7,389	4,884	2,260
30-min	143,809	65,340	111,165	50,747	32,644	14,593
45-min	320,387	143,173	270,570	120,051	49,817	23,122
60-min	386,574	171,603	398,445	176,755	-11,871	-5,152

Heritage Greene Terminal

Proposed Network Reconfiguration | **Existing HSR Network**

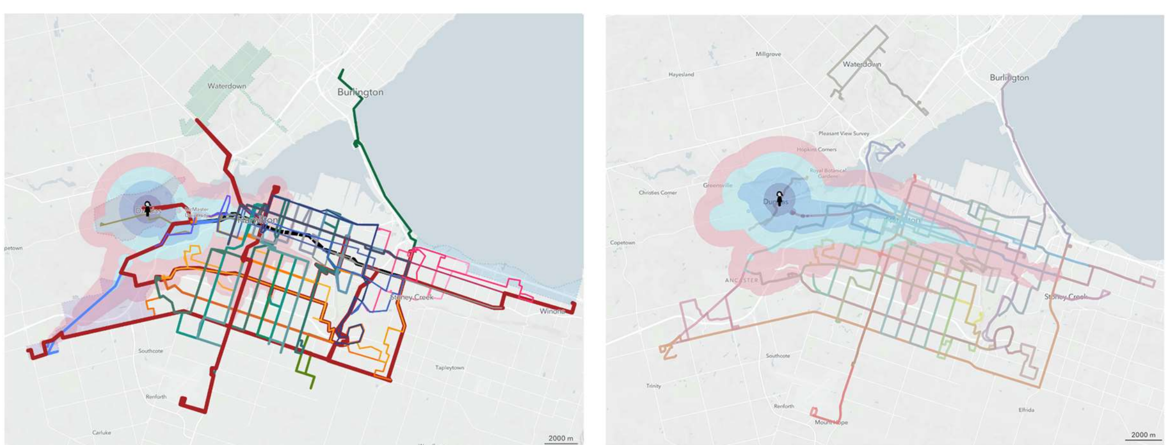


15-min Travel Time | 30-min Travel Time | 45-min Travel Time | 60-min Travel Time

Travel time	Proposed Network		Existing Network		Difference	
	Population	Employed	Population	Employed	Population	Employed
15-min	3,688	1,898	4,467	2,330	-779	-432
30-min	73,801	34,131	1,683	10,280	72,118	23,851
45-min	314,814	139,739	135,608	64,075	179,206	75,664
60-min	417,041	185,783	304,433	139,931	112,608	45,852

Dundas Downtown

Proposed Network Reconfiguration | **Existing HSR Network**



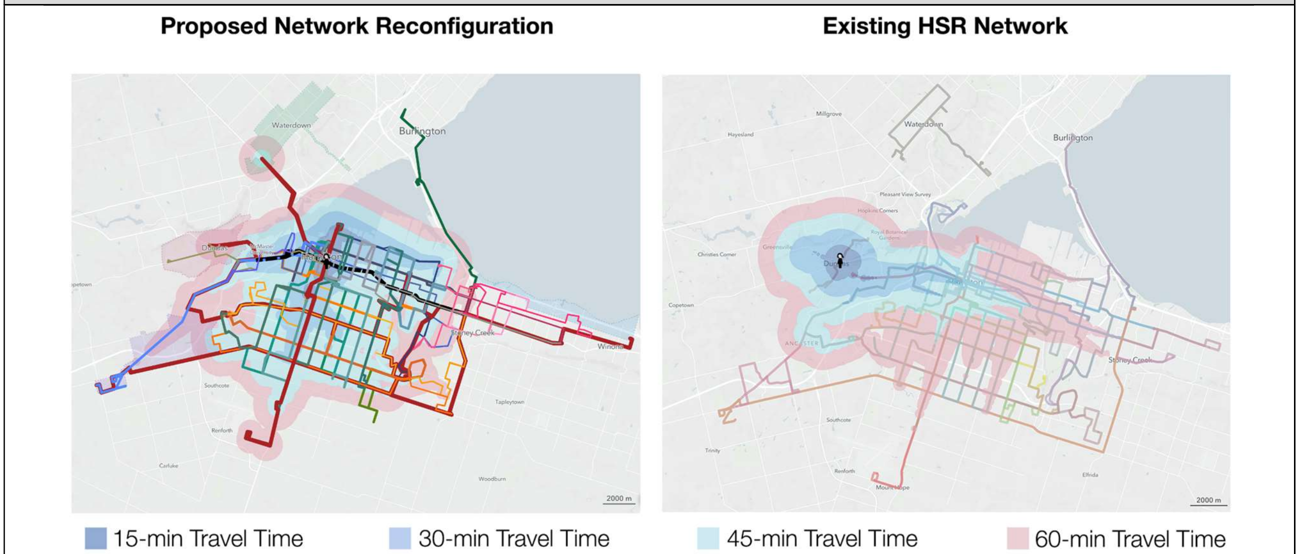
15-min Travel Time | 30-min Travel Time | 45-min Travel Time | 60-min Travel Time

Travel time	Proposed Network	Existing Network	Difference

	Population	Employed	Population	Employed	Population	Employed
15-min	6,613	2,505	6,927	2,690	-314	-185
30-min	22,336	9,477	34,946	15,016	-12,610	-5,539
45-min	63,818	28,027	104,951	45,808	-41,133	-17,781
60-min	173,612	76,008	217,212	95,033	-43,600	-19,025

Table 3-5: Comparisons between existing and proposed HSR network (08:00 Sunday)

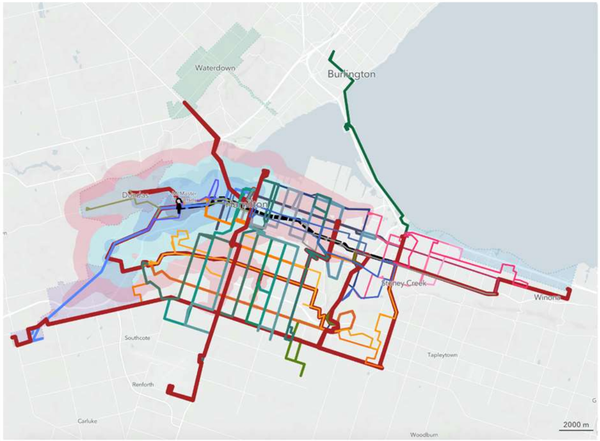
Downtown



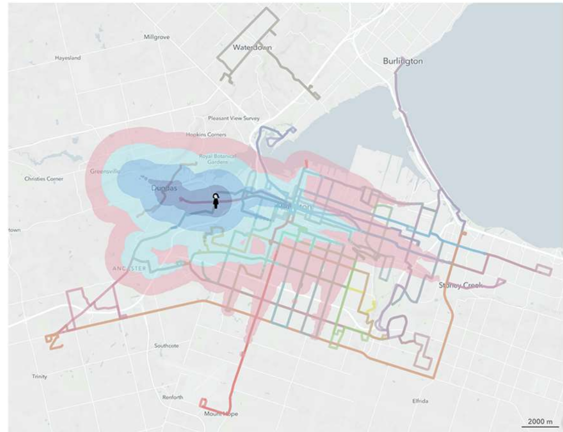
Travel time	Proposed Network		Existing Network		Difference	
	Population	Employed	Population	Employed	Population	Employed
15-min	35,183	15,077	19,422	8,392	15,761	6,685
30-min	119,037	51,672	79,576	34,617	39,461	17,055
45-min	311,266	137,234	237,615	105,526	73,651	31,708
60-min	385,545	170,197	366,780	161,079	18,765	9,118

McMaster University

Proposed Network Reconfiguration



Existing HSR Network



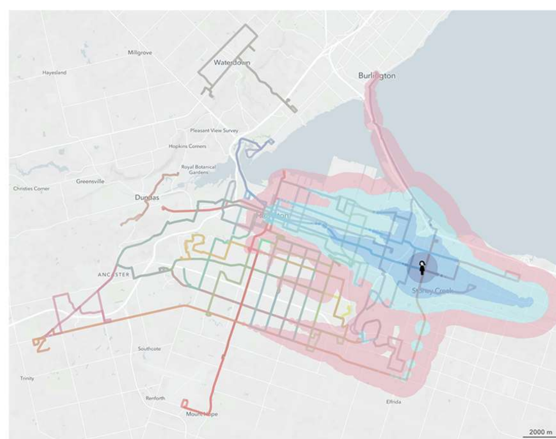
15-min Travel Time | 30-min Travel Time | 45-min Travel Time | 60-min Travel Time

Travel time	Proposed Network		Existing Network		Difference	
	Population	Employed	Population	Employed	Population	Employed
15-min	4,695	2,007	12,483	5,326	-7,788	-3,319
30-min	40,525	17,201	92,860	40,885	-52,335	-23,684
45-min	117,925	50,110	249,369	110,677	-131,444	-60,567
60-min	227,113	99,503	373,630	164,617	-146,517	-65,114

Eastgate Terminal

Proposed Network Reconfiguration

Existing HSR Network

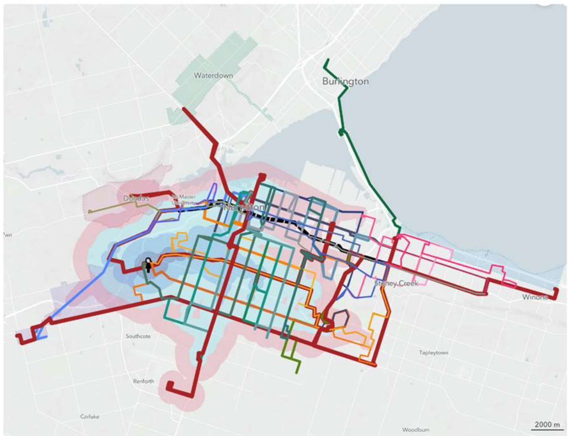


15-min Travel Time | 30-min Travel Time | 45-min Travel Time | 60-min Travel Time

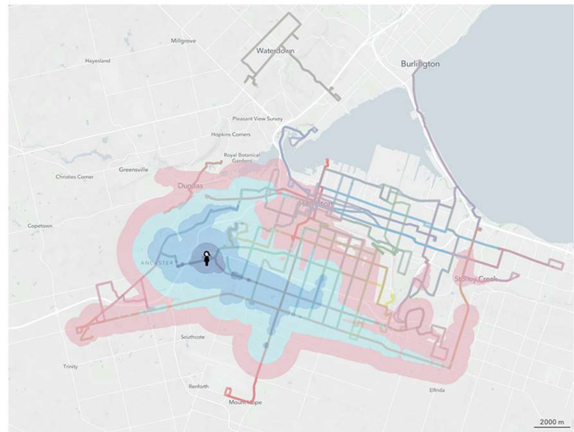
Travel time	Proposed Network		Existing Network		Difference	
	Population	Employed	Population	Employed	Population	Employed
15-min	19,895	7,794	17,712	7,087	2,183	707
30-min	93,155	39,968	104,201	44,386	-11,046	-4,418
45-min	222,105	96,995	206,155	90,397	15,950	6,598
60-min	362,233	160,647	361,200	160,349	1233	298

Meadowlands Terminal

Proposed Network Reconfiguration



Existing HSR Network

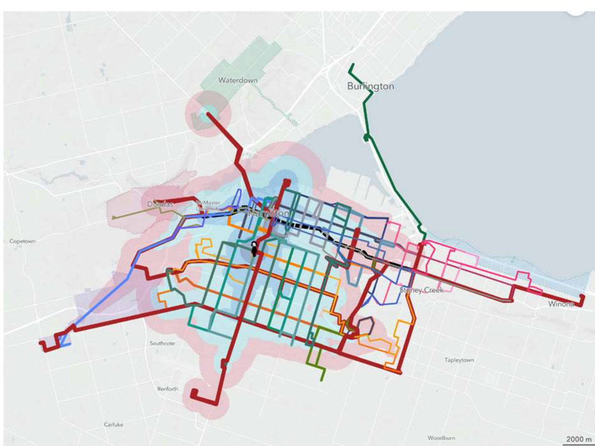


15-min Travel Time | 30-min Travel Time | 45-min Travel Time | 60-min Travel Time

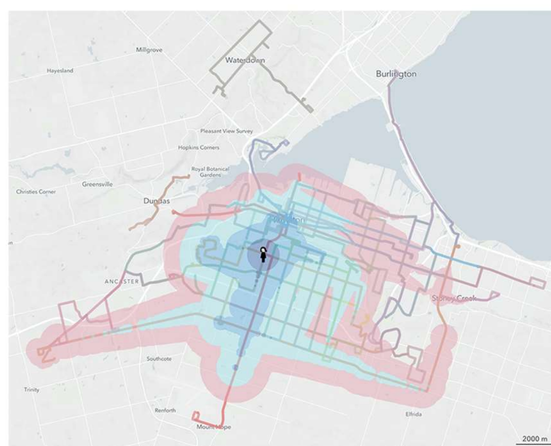
Travel time	Proposed Network		Existing Network		Difference	
	Population	Employed	Population	Employed	Population	Employed
15-min	9,568	3,851	5,273	2,233	4,295	1,618
30-min	79,312	34,909	56,408	25,202	22,904	9,707
45-min	224,142	99,233	167,212	74,178	56,930	25,055
60-min	333,246	147,702	324,068	143,363	9,178	4,339

Mohawk College

Proposed Network Reconfiguration



Existing HSR Network

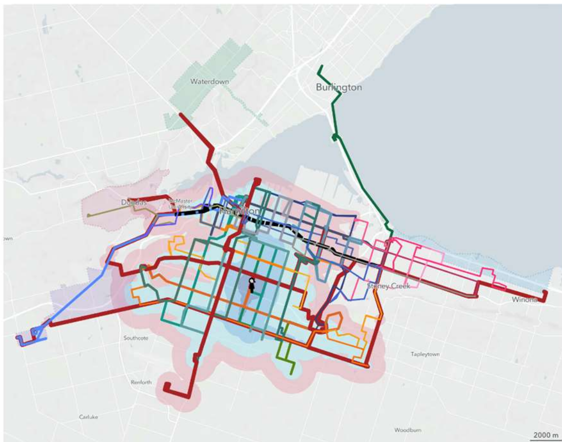


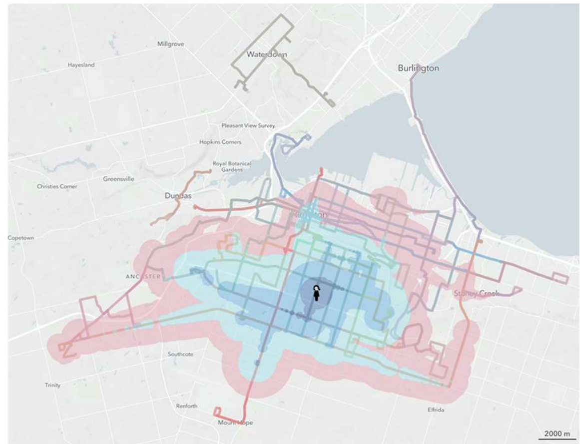
15-min Travel Time | 30-min Travel Time | 45-min Travel Time | 60-min Travel Time

Travel time	Proposed Network		Existing Network		Difference	
	Population	Employed	Population	Employed	Population	Employed
15-min	17,923	7,859	18,375	8,454	-452	-595
30-min	108,148	47,387	119,992	51,960	-11,844	-4,573
45-min	279,867	122,776	297,413	130,901	-17,546	-8,125
60-min	36,540	161,440	402,660	177,537	-366,120	-16,097

CF Lime Ridge Mall

Proposed Network Reconfiguration | **Existing HSR Network**





15-min Travel Time | 30-min Travel Time | 45-min Travel Time | 60-min Travel Time

Travel time	Proposed Network		Existing Network		Difference	
	Population	Employed	Population	Employed	Population	Employed
15-min	10,754	4,594	9,312	4,000	1,442	594
30-min	78,071	35,672	76,803	35,011	1,268	661
45-min	251,152	111,777	235,001	103,070	16,151	8,707
60-min	346,715	154,632	369,328	163,911	-22,613	-9,279

Heritage Greene Terminal

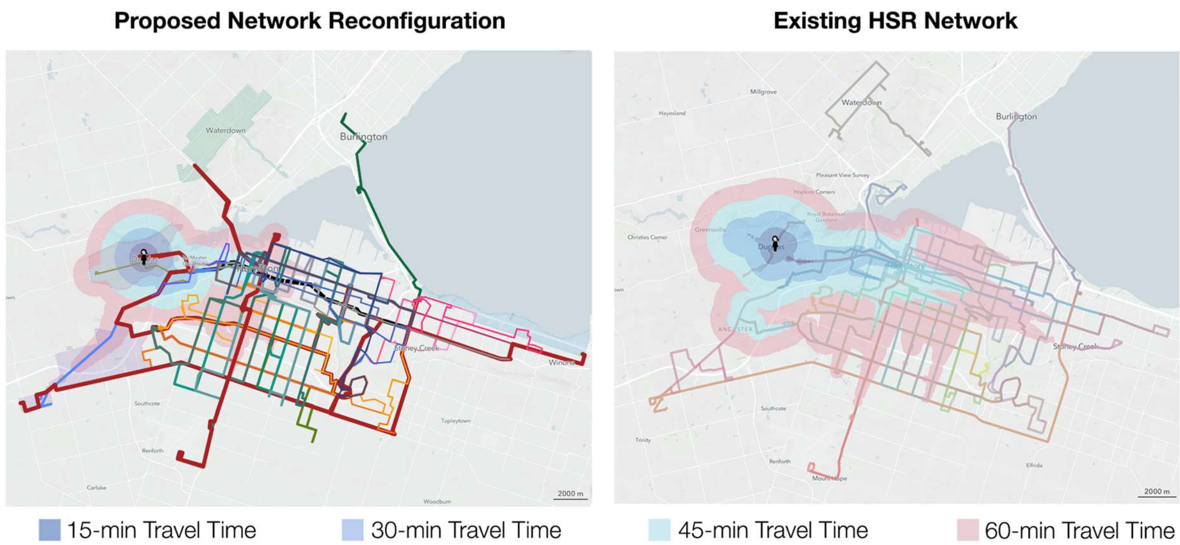
Proposed Network Reconfiguration | **Existing HSR Network**

15-min Travel Time | 30-min Travel Time | 45-min Travel Time | 60-min Travel Time

Travel time	Proposed Network		Existing Network		Difference	
	Population	Employed	Population	Employed	Population	Employed
15-min	3,445	1,782	6,728	3,249	-3,283	-1,467
30-min	59,979	28,119	60,275	28,140	-296	-21

45-min	260,948	114,824	194,145	89,317	66,803	25,507
60-min	397,598	176,965	371,808	165,297	25,790	11,668

Dundas Downtown



Travel time	Proposed Network		Existing Network		Difference	
	Population	Employed	Population	Employed	Population	Employed
15-min	6,613	2,505	6,816	2,630	-203	-125
30-min	22,281	9,456	32,105	3,665	-9,824	5,791
45-min	46,720	28,385	108,398	47,628	-61,678	-19,243
60-min	156,576	67,698	259,937	144,168	-103,361	-76,470

3.4. Connectivity Analysis

The connectivity analysis is the core building block for the proposed network. The analysis of users' preferences highlighted that reducing the number of transfers is the key contributing factor to enhance ridership rates. As such, the proposed network provides superior connectivity performance compared to the current network based on all connectivity measures. The proposed network, attributed to the hierarchical structure, provides direct (no transfer) connection between its eight hubs.

Table 3-6: Hub-to-Hub connectivity

	CF Lime Ridge Terminal	Eastgate Terminal	Heritage Greene Terminal	King & James	McMaster University Terminal	Meadowlands Terminal	Mohawk College Terminal	West Harbour GO Terminal
CF Lime Ridge Terminal	X	0 Transfers	0 Transfers	0 Transfers	0 Transfers	0 Transfers	0 Transfers	0 Transfers
Eastgate Terminal	0 Transfers	X	0 Transfers	0 Transfers	0 Transfers	0 Transfers	0 Transfers	0 Transfers
Heritage Greene Terminal	0 Transfers	0 Transfers	X	0 Transfers	0 Transfers	0 Transfers	0 Transfers	0 Transfers
King & James	0 Transfers	0 Transfers	0 Transfers	X	0 Transfers	0 Transfers	0 Transfers	0 Transfers
McMaster University Terminal	0 Transfers	0 Transfers	0 Transfers	0 Transfers	X	0 Transfers	0 Transfers	0 Transfers

Meadowlands	0 Transfers	0 Transfers	0 Transfers	0 Transfers	0 Transfers	X	0 Transfers	0 Transfers
Mohawk College	0 Transfers	0 Transfers	0 Transfers	0 Transfers	0 Transfers	0 Transfers	X	0 Transfers
West Harbour GO	0 Transfers	0 Transfers	0 Transfers	0 Transfers	0 Transfers	0 Transfers	0 Transfers	X

** Shaded cells represent BLAST connection between hubs.*

Table 3-7: Connectivity of major destinations (Proposed Network)

	Ancaster Fairgrounds Gateway	Centre Mall Terminal	CF Lime Ridge Terminal	Confederation GO Terminal	Downtown Dundas Terminal	Eastgate Terminal	Elfrida Gateway	Hamilton GO Centre	Heritage Greene Terminal	King & James	McMaster University Terminal	Meadowlands Terminal	Mohawk College Terminal	Mountain Transit Centre	Parkdale Terminal	Stoney Creek Gateway	Waterdown Gateway	West Harbour GO Terminal
% In Compliance	100%	100%	100%	100%	94%	100%	94%	100%	100%	100%	100%	100%	100%	94%	100%	88%	94%	100%
Ancaster Fairgrounds Gateway	x	1	1	1	1	1	1	1	0	1	0	0	1	1	0	1	1	0
Centre Mall Terminal	1	x	0	1	1	1	1	0	1	0	1	1	0	1	0	1	0	0
CF Lime Ridge Terminal	1	0	x	1	0	0	1	0	0	0	0	0	0	1	1	1	0	0
Confederation GO Terminal	1	1	1	x	1	0	0	1	0	1	1	1	1	1	1	1	1*	0*
Downtown Dundas Terminal	1	1	0	1	x	1	1	0	0	0	0	1	1	1	1	2 Transfers	1	1
Eastgate Terminal	1	1	0	0	0	x	0	1	0	0	0	1	1	1	0	0	1	1
Elfrida Gateway	1	1	1	0	1	0	x	1	0	1	1	1	1	1	1	1	2 Transfers	1
Hamilton GO Centre	1	0	0	1	0	1	1	x	1	0	0	0	0	0	1	1	0	0*
Heritage Greene Terminal	0	1	0	0	1	0	0	1	x	0	0	0	0	1	0	1	1	1
King & James	1	0	0	1	0	0	1	0	0	x	0	0	0	0	0	1	0	0
McMaster University Terminal	0	1	0	1	0	0	1	0	0	0	x	0	1	1	0	1	1	1
Meadowlands Terminal	0	1	0	1	1	1	1	0	0	0	0	x	0	1	1	1	1	0
Mohawk College Terminal	1	0	0	1	1	1	1	0	0	0	1	0	x	0	1	1	0	0
Mountain Transit Centre	1	1	1	1	1	1	1	0	1	0	1	1	0	x	1	2 Transfers	1	0
Parkdale Terminal	0	0	1	1	1	0	1	1	0	0	0	1	1	1	x	0	1	1
Stoney Creek Gateway	1	1	1	1	2 Transfers	0	1	1	1	1	1	1	1	2 Transfers	0	x	1	1
Waterdown Gateway	1	0	0	1	1	1	2 Transfers	0	1	0	1	1	0	1	1	1	x	0*
West Harbour GO Terminal	0	0	0	0*	1	1	1	0*	1	0	1	0	0	0	1	1	1*	x

Primary Hub to Primary Hub: Zero Transfers
Primary Hub to Secondary Hub: maximum one Transfer
Secondary Hub to Secondary Hub: One Transfer
**Uses GO Transit for part of trip (assumes train service between Aldershot, West Harbour, & Confederation GOs)*

Table 3-8: Connectivity of major destinations (current network)

	Ancaster Fairgrounds Gateway	Centre Mall Terminal	CF Lime Ridge Terminal	Confederation GO Terminal	Downtown Dundas Terminal	Eastgate Terminal	Elfrida Gateway	Hamilton GO Centre	Heritage Greene Terminal	King & James	McMaster University Terminal	Meadowlands Terminal	Mohawk College Terminal	Mountain Transit Centre	Parkdale Terminal	Stoney Creek Gateway	Waterdown Gateway	West Harbour GO Terminal
% In Compliance	**0%**	**82%**	**71%**	**94%**	**76%**	**88%**	**82%**	**88%**	**88%**	**94%**	**82%**	**82%**	**82%**	**82%**	**88%**	**47%**	**18%**	**82%**
Ancaster Fairgrounds Gateway	X	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP
Centre Mall Terminal	NP	X	0	1	1	1	1	0	1	0	1	1	1	1	1	2	2	1
CF Lime Ridge Terminal	NP	0	X	1	1	1	1	0	0	0	2	1	1	1	1	2	2	2
Confederation GO Terminal	NP	1	1	X	1	0	0	1	0	1	1	1	1	1	1	1	1	0*
Downtown Dundas Terminal	NP	1	1	1	X	1	2	0	1	0	0	1	1	1	1	2	2	1
Eastgate Terminal	NP	1	1	0	1	X	0	1	0	1	0	1	1	1	0	0	2	1
Elfrida Gateway	NP	1	1	0	2	0	X	1	0	1	1	1	1	1	1	0	3	1
Hamilton GO Centre	NP	0	0	1	0	1	1	X	1	0	0	0	0	0	1	1	2	0*
Heritage Greene Terminal	NP	1	0	0	1	0	0	1	X	1	1	0	0	1	0	1	2	1
King & James	NP	0	0	1	0	0	1	0	1	X	0	0	0	0	0	1	1	0
McMaster University Terminal	NP	1	2	1	0	0	1	0	1	0	X	0	1	1	0	1	2	1
Meadowlands Terminal	NP	1	1	1	1	1	1	0	0	0	0	X	1	1	1	2	2	1
Mohawk College Terminal	NP	1	1	1	1	1	1	0	0	0	1	1	X	0	1	2	2	0
Mountain Transit Centre	NP	1	1	1	1	1	1	0	1	0	1	1	0	X	1	2	2	0
Parkdale Terminal	NP	1	1	1	1	0	1	1	0	0	0	1	1	1	X	1	2	1
Stoney Creek Gateway	NP	2	2	1	2	0	1	1	1	1	1	2	2	2	1	X	3	2
Waterdown Gateway	NP	2	2	1*	2	2	3	2	2	1	2	2	2	2	2	3	X	1*
West Harbour GO Terminal	NP	1	2	0*	1	1	1	0*	1	0	1	1	0	0	1	2	1*	X

**Uses GO Transit for part of trip (assumes train service between Aldershot, West Harbour, & Confederation GOs)*

NP = Not possible

Furthermore, the metrics displayed in Table 3-7 and Table 3-8 provide clear indications on the higher connectivity between major destinations at the city of Hamilton.

Table 3-9: Connectivity analysis (proposed vs. Current network)

	Proposed Network	Current Network	Connectivity Difference
Average %	**98%**	**74%**	**24%**
Ancaster Fairgrounds Gateway	100%	0%	100%
Centre Mall Terminal	100%	82%	18%
CF Lime Ridge Terminal	100%	71%	29%
Confederation GO Terminal	100%	94%	6%
Downtown Dundas Terminal	94%	76%	18%
Eastgate Terminal	100%	88%	12%
Elfrida Gateway	94%	82%	12%
Hamilton GO Centre	100%	88%	12%
Heritage Greene Terminal	100%	88%	12%
King & James	100%	94%	6%
McMaster University Terminal	100%	82%	18%
Meadowlands Terminal	100%	82%	18%
Mohawk College Terminal	100%	82%	18%
Mountain Transit Centre	94%	82%	12%
Parkdale Terminal	100%	88%	12%
Stoney Creek Gateway	88%	47%	41%
Waterdown Gateway	94%	18%	76%
West Harbour GO Terminal	100%	82%	18%

3.5. Network Robustness Assessment

There are no universal definitions of network robustness in the transportation context. While this report does not aim to resolve this issue, the report adopts the following definitions in the context of the present study. ***Static-robustness*** is defined as *"a holistic network-level measure that quantifies the overall network performance as a function of its comprising components."*

In this respect, the HSR network robustness is evaluated using three static measures. These measures consider the spatial arrangements routes, directions, and stops, as well as some of the temporal aspects such as service frequency. While it falls short in accommodating service occupancy features service such as bus occupancy. The three measures implemented herein are frequently utilized in the literature and include:

The Robustness Indicator (R^t) (Eq. 1) relates the robustness of the service based on the number of alternative routes between stations, as an indication of the integrity of the network.

$$\text{Robustness Indicator} \quad R^t = \frac{L_T - N_{TE} - L_m + 1}{N_{Total}} \qquad (1)$$

While the Robustness Metric (r^T) (Eq. 2) does not consider the number of multiple routes operating on the same link in the estimation of network robustness.

$$\text{Robustness Metric} \quad r^T = \frac{\ln{(L_T - N_{TE} + 2)}}{N_{Total}} \qquad (2)$$

The Critical Threshold (f_c) refers to the fraction (number) of non-operational stations that causes a completely disconnected network (Eq. 3).

$$\text{Critical Threshold} \qquad f_c = 1 - \frac{1}{\frac{K_{av.}^2}{K_{av.}} - 1} \quad (3)$$

These measures were applied at the network-level for the existing HSR operation and the proposed reconfiguration. The values of these measures are used to compare the robustness of the two alternatives as a holistic assessment of network robustness.

The robustness assessment results are illustrated in Table 3-10. The results indicate that the proposed network is more robust across all measures.

In other words, the magnitude of the cascading impacts (e.g., cancelled trips, delayed trips, etc.) arising from any incident during operation in the proposed network is less sever compared to the existing network.

Table 3-10. Robustness Assessment of HSR Network

Network	Robustness Indicator $\mathbf{R^t}$	Robustness Metric r^T	Critical Threshold $\mathbf{f_c}$
Existing HSR Network	0.201	0.014	0.692
Proposed Reconfiguration	0.408	0.221	0.873

3.6. Assessment of Reconfiguration Guidelines

The proposed network fulfills all the reconfiguration guidelines introduced in Chapter 2, which in turn were based on the data collection, modelling, and analysis of Hamiltonians' needs from HSR. Revisiting these guidelines is critical to evaluate the proposed network.

Hub-to-Hub No-Transfer Service

- There are direct trips (no transfer) that connect the eight proposed transit hubs in Hamilton.
- The current HSR network falls short in providing such connectivity as the network is not designed based on a hierarchical process.

Hub-to-Origin/Designation One-Transfer Service

- Each transit hub is supported by local routes that provide access to the local community. Therefore, any trip connecting the HSR hubs to/from any place in Hamilton would be carried out with only one transfer. Often, this transfer is to a higher-order transit service (i.e., Express and BRT).
- Most of the trips in the current network requires approximately two transfers.

Higher-Order Fast-Frequent Transit Service

- Relative to the existing network, the proposed reconfiguration provides a higher level of service and frequencies. Further, it provides higher order-based service, which in turn enables Hamiltonians to entertain several options while travelling within the city and to regional connectivity.
- The higher-order is established from a clear service hierarchy in the proposed five-tier route classification.

Regional-Connectivity

- The proposed network provides regional connectivity to Go Services (Bus and Rail) through three dedicated regional routes and four express routes, and 12 collector routes.

Resilient & Robust Network

- The proposed network exhibits a higher overall network robustness index. This is attributed to the integration between grid, radial, and local routes, as well as the hierarchical nature of the routes.

Last-Mile Accessibility All Week

- *Last-mile access through local routes is provided all week with a minimum of 30 minutes headway (2 buses per hour).*

Demand-based Stop/Infrastructure Planning

- Although the proposed two BRT routes will contribute to addressing Hamiltonians needs for weather protection at stop and will increase the spacing between stops, additional efforts are required to guide the infrastructure (stops/station) planning process. This is fundamental for the successful implementation of the proposed reconfiguration.

Enhanced & Reliable Level of Service

- Although not observed from the network reconfiguration, it is strongly recommended to implement a continuous improvement loop with its focus on improving transit network speed and reliability. This could be established through a new unit/department within the HSR. This is fundamental to address/smooth any service disruptions during daily operations. Such a department would also be responsible for updating the on-time performance matrix to ensure a reliable level of service.

CHAPTER 4

DATA-driven Reconfiguration Process

4. Data-driven Reconfiguration Process

The reconfiguration process is informed by a wealth of data and models detailed in Reports 1 & 2. First, the HSR public survey data is utilized to model Hamiltonians' preferences towards the HSR service attributes. The survey is aimed at assessing the quality of HSR service based on user preferences and expectations. The survey is intended for those who currently use HSR service or may in the future. The McMaster Research Ethics Board (MREB) approved the survey on July 18th, 2018. Two waves of data collection have been completed in September 2018 and April 2019. The survey is structured into five main sections, including socioeconomic and demographics, travel behaviour and mobility options, HSR perceived and desired quality, stated preferences experiment, and attitudinal and behavioural orientations. Second, the HSR operation and infrastructure data is used to benchmark the service performance across both spatial (infrastructure distribution) and temporal (on-time performance) dimensions.

While Hamilton prides itself on being “A City of Many Communities,” it is the HSR’s role to connect those communities together. By having a transit system that provides quality service to the entire city, it promotes and distributes economic prosperity, provides environmental benefits, and improves the quality of life.

For that system to truly function effectively, routes and service levels within those communities must be determined by overarching city-building goals and data. Efficiencies and attractiveness of a transit system as a choice mode of travel should be built around the overarching holistic City building goals and not based on individual communities’ support or non-support of transit.

Overall, this chapter bridges the findings from user engagement models and service benchmarking assessments from one hand and the proposed service configuration from the other hand.

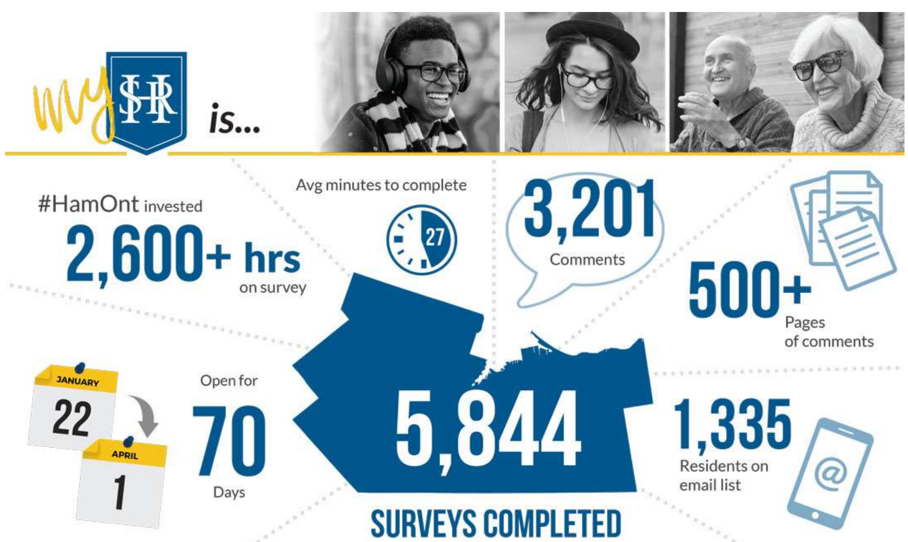


Figure 4-1. Infographic of HSR Public Survey

The reconfiguration process draws upon the findings derived from user preferences models as well as service operation benchmarking, land use development, and travel demand in Hamilton. The following sub-sections provide a brief description of the models utilized to inform the reconfiguration philosophy. It should be noted that the details of the modelling efforts are provided in previous reports.

4.1. Importance Performance Analysis (IPA)

The IPA model integrates the relative importance of each service attribute with the associated level of satisfaction expressed towards these attributes. IPA models are beneficial for the microscopic analysis, explicitly to depict the differences between the desired and perceived levels of quality, with the aim of identifying attributes that will provide the most significant improvement to overall service satisfaction. The results of the IPA models are graphically displayed on a two-dimensional matrix, the x-axis represents satisfaction (performance), and the y-axis represents importance, which forms four quadrants, as shown in Figure 4-2 .

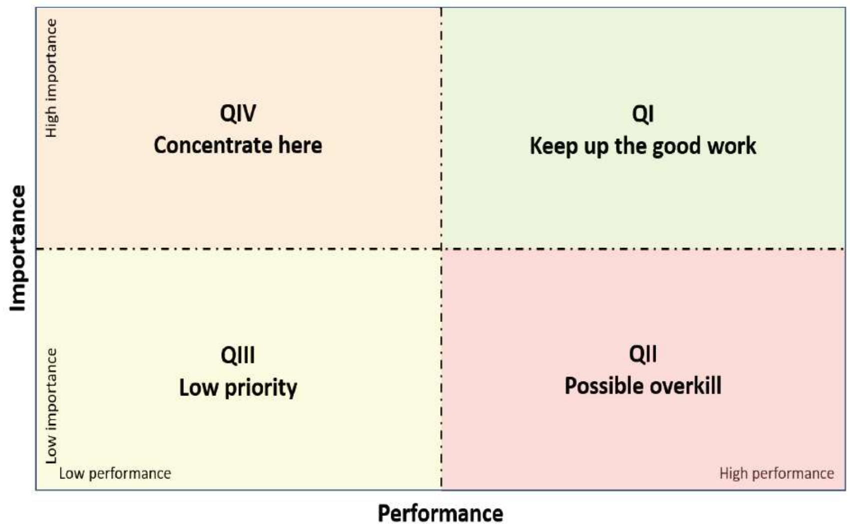


Figure 4-2: The IPA matrix quadrants

The IPA was applied to the entire sample as well as on the route-level. The results of the IPA informed the network reconfiguration task by prioritizing transit service aspects.

4.2. Transportation Tomorrow Survey (TTS)

The 2016 Transportation Tomorrow Survey (TTS), which is administered by the Data Management Group at the University of Toronto, is utilized to characterize, and understand trip-making behaviour in Hamilton. The TTS survey utilizes a large sample of households in the Greater Golden Horseshoe region and aims to understand the travel behaviour in a typical weekday for the sampled households. The 2016 data first became available in early 2018 and introduced a full range of intra-metropolitan trip-types, such as journey-to-work, discretionary, and others. In the current analysis, all trip purposes are included in aggregate traffic analysis zones. Table 4-1 shows the total daily Origin-Destination (OD) matrix for transit trips based on 19 aggregated zones representing the City of Hamilton.

Table 4-1: Total daily flow of transit trips

	Arrive																			
Depart	Downtown	Dundurn	Westdale	Central	East	Industrial	West Mo..	Central M..	East Mou..	Rosedale..	East Ston..	West Sto..	Upper St..	Dundas	Waterdo..	Ancaster	Ancaster ..	Glanbrook	Flamboro..	Grand To..
Downtown	1,613	449	2,611	1,465	1,148	0	1,436	1,674	447	225	121	308	116	315	0	226	0	0	40	12,194
Dundurn	504	90	473	338	175	55	339	213	26	29	0	203	0	23	0	21	0	26	0	2,515
Westdale	2,751	421	3,211	1,267	407	62	494	679	87	0	243	247	81	382	0	395	0	0	0	10,727
Central	1,334	255	1,150	1,024	697	249	863	434	32	180	67	593	0	144	27	17	0	36	0	7,102
East	1,225	175	445	452	416	43	486	70	83	267	95	888	0	30	0	0	28	0	0	4,703
Industrial	0	55	62	198	43	0	0	56	0	0	31	86	15	0	0	0	0	0	0	546
West Mountain	1,385	282	665	738	486	0	1,857	1,662	730	118	48	233	64	143	0	103	0	0	0	8,514
Central Mountain	1,634	230	849	592	121	56	1,637	2,490	632	49	27	126	113	26	0	101	30	0	57	8,770
East Mountain	341	0	87	76	37	0	633	658	324	0	0	0	92	34	0	0	0	0	0	2,282
Rosedale/ Red Hill	254	29	26	180	181	0	89	49	0	66	0	290	0	0	0	0	0	0	0	1,164
East Stoney Creek	69	0	340	149	244	31	150	27	0	0	134	144	0	100	0	0	0	0	0	1,388
West Stoney Creek	353	203	129	434	897	86	255	131	0	359	144	515	87	0	0	44	0	0	0	3,637
Upper Stoney Creek	116	0	170	0	0	15	64	93	79	0	0	61	0	59	0	0	0	7	0	664
Dundas	367	23	722	61	0	0	177	85	0	0	0	0	0	52	0	0	0	0	0	1,487
Waterdown	0	0	0	54	0	0	0	0	0	0	0	0	0	0	0	0	0	0	13	67
Ancaster	177	0	292	0	0	0	125	92	18	0	0	44	0	0	0	0	16	0	0	764
Ancaster (Rural)	0	0	0	0	0	0	110	61	0	0	0	0	0	0	0	126	0	0	0	297
Glanbrook	0	26	0	36	0	0	0	0	0	0	0	0	7	0	0	0	0	0	0	69
Flamborou..	40	0	0	0	0	0	0	57	0	0	0	0	0	0	13	0	0	0	0	110
Grand Total	12,163	2,238	11,232	7,064	4,852	597	8,715	8,531	2,458	1,293	910	3,738	575	1,308	40	1,033	74	69	110	67,000

Depart	Arrive: Downtown	Dundurn	Westdale	Central	East	Industrial	West Mo..	Central M..	East Mou..	Rosedale..	East Ston..	West Sto..	Upper St..	Dundas	Waterdo..	Ancaster	Ancaster ..	Glanbrook	Flamboro..	Grand To..
Downtown	1,613	449	2,611	1,465	1,148	0	1,436	1,674	447	225	121	308	116	315	0	226	0	0	40	12,194
Dundurn	504	90	473	338	175	55	339	213	26	29	0	203	0	23	0	21	0	26	0	2,515
Westdale	2,751	421	3,211	1,267	407	62	494	679	87	0	243	247	81	382	0	395	0	0	0	10,727
Central	1,334	255	1,150	1,024	697	249	863	434	32	180	67	593	0	144	27	17	0	36	0	7,102
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Industrial	0	55	62	198	43	0	0	56	0	0	31	86	15	0	0	0	0	0	0	546
West Mountain	1,385	282	665	738	486	0	1,857	1,662	730	118	48	233	64	143	0	103	0	0	0	8,514
Central Mountain	1,634	230	849	592	121	56	1,637	2,490	632	49	27	126	113	26	0	101	30	0	57	8,770
East Mountain	341	0	87	76	37	0	633	658	324	0	0	0	92	34	0	0	0	0	0	2,282
Rosedale/ Red Hill	254	29	26	180	181	0	89	49	0	66	0	290	0	0	0	0	0	0	0	1,164
East Stoney Creek	69	0	340	149	244	31	150	27	0	0	134	144	0	100	0	0	0	0	0	1,388
West Stoney Creek	353	203	129	434	897	86	255	131	0	359	144	515	87	0	0	44	0	0	0	3,637
Upper Stoney Creek	116	0	170	0	0	15	64	93	79	0	0	61	0	59	0	0	0	7	0	664
Dundas	367	23	722	61	0	0	177	85	0	0	0	0	0	52	0	0	0	0	0	1,487
Waterdown	0	0	0	54	0	0	0	0	0	0	0	0	0	0	0	0	0	0	13	67
Ancaster	177	0	292	0	0	0	125	92	18	0	0	44	0	0	0	0	16	0	0	764
Ancaster (Rural)	0	0	0	0	0	0	110	61	0	0	0	0	0	0	0	126	0	0	0	297
Glanbrook	0	26	0	36	0	0	0	0	0	0	0	0	7	0	0	0	0	0	0	69
Flamborou..	40	0	0	0	0	0	0	57	0	0	0	0	0	0	13	0	0	0	0	110
Grand Total	12,163	2,238	11,232	7,064	4,852	597	8,715	8,531	2,458	1,293	910	3,738	575	1,308	40	1,033	74	69	110	67,000

From the TTS data, the analysis utilized the data associated with 234 Traffic Analysis Zones (TAZs) that represent the City of Hamilton. The O-D matrices are constructed to represent daily (all travel modes) interzonal trip flow as well as trips between all zones. The O-D matrices help to:

1) Better understand trip-making behaviour in Hamilton for all travel modes,
2) Better understand the geography of trips, trip volumes, and mode-shares associated with key origins and destinations, and
3) Interpret identifiable patterns in terms of how they link to existing HSR routes and possible implications.

This, in turn, provides an additional lens to support the allocation of HSR services.

4.3. Benchmarking HSR service

Benchmarking the HSR service from an operational perspective is of utmost importance for identifying the gaps and better-allocating HSR resources. The assessment of service allocation, productivity, and operation was utilized to inform the following aspects:

1) Examining the HSR service allocation including route frequency and stop utilization, and highlighting the variation on service allocation over time and space,
2) Estimating route productivity index as a function of ridership rates and the desired occupancy for each route, and
3) Assessing the reliability of HSR operation and service on-time performance indices at both route- and stop-levels.

Figure 4-3 shows a sample of the Stop Utilization Index (i.e., one of the indices used in benchmarking the service). The Stop Utilization Index demonstrates the number of buses per hour serving each stop. The benchmarking of existing transit service informs the reconfiguring of the network by identifying where deficiencies in the current system are present and where service is under or over-utilized. Further, it informs the required modifications for existing service operation standards and the dire need for a continued monitoring HSR service operation and planning.

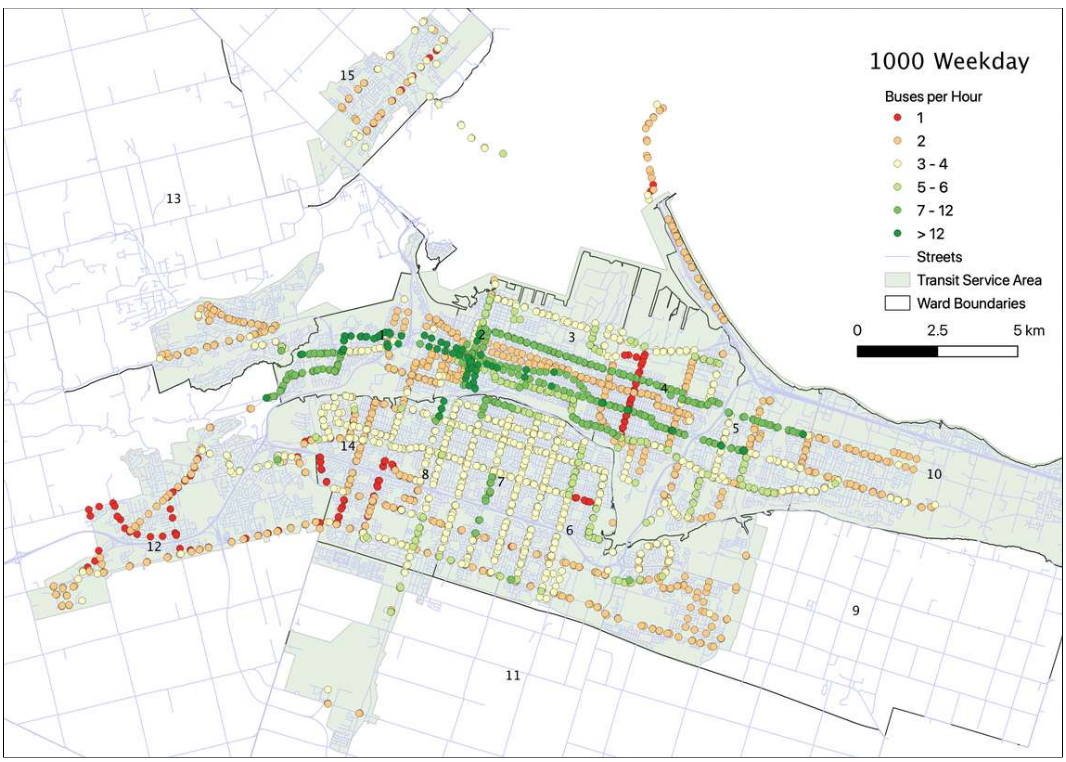


Figure 4-3: Sample of Stop Utilization Index (Weekday – 10:00 AM)

4.4. Desired and Perceived Quality

The desired quality from HSR service, for all respondents, is evaluated based on a self-reported level of importance associated with 30 suggested service improvements. In addition to identifying the HSR desired service quality, the variation of the desired quality measures is tested across routes as well as across different socio-economic demographic characteristics. Figure 4-4 shows the importance of HSR service improvements as an example.

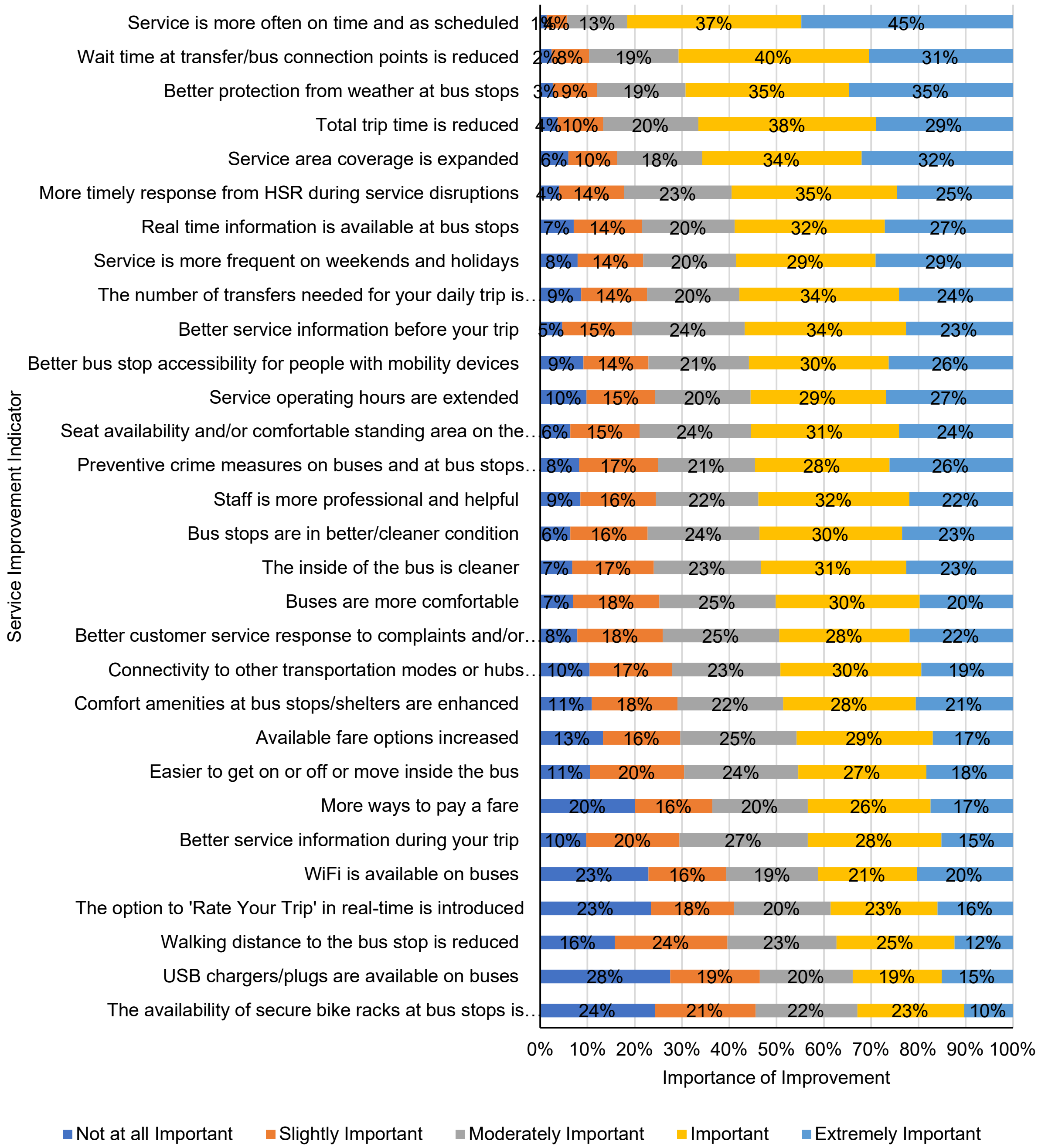


Figure 4-4: Importance of improvements to HSR service

While the perceived quality from HSR service, for transit users only, is evaluated based on consumers' self-reported satisfaction of 29 service indicators. Also, the variation of HSR perceived service quality is tested across different routes and socioeconomic demographic characteristics.

Taken together, the desired and perceived quality measures identify the necessary aspects to satisfy current users and attract potential users, hence informing network reconfiguration. Figure 4-5 shows the satisfaction level associated with different HSR aspects.

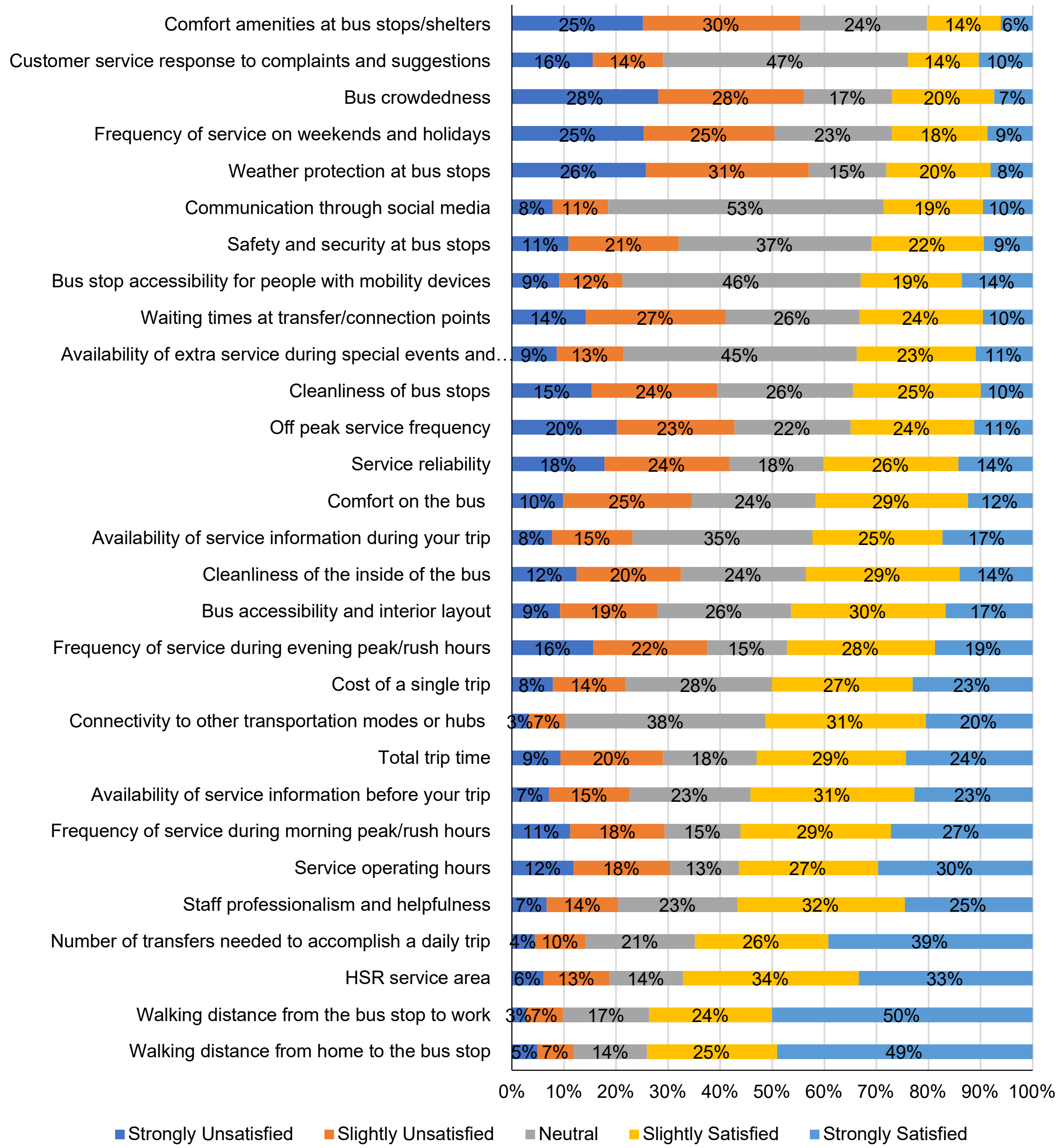


Figure 4-5: Satisfaction level associated with HSR service aspects.

4.5. Willingness To Pay Models

Willingness to pay (WTP) estimates for service improvements are based on advanced statistical models, and the data derived from two Stated Choice Experiments: labelled and unlabelled. WTP estimates are also an implicit way of presenting customer preferences towards service attributes. WTP estimates were calculated for daily, regular, and infrequent customers. WTP estimates are used to identify the influence of each service attributes on the overall transit utility and mode choice.

Table 4-2 shows the willingness to pay estimates for service improvements regarding the unlabelled choice experiment.

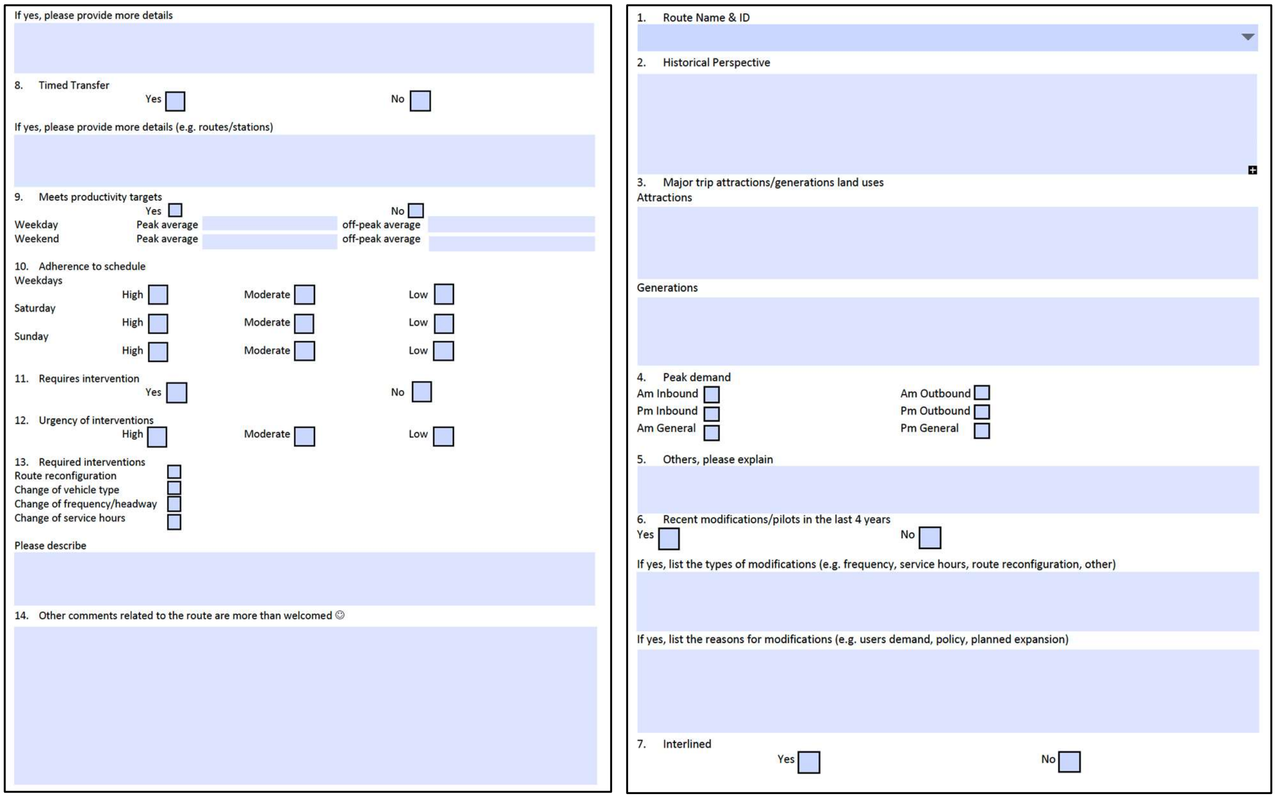
Table 4-2: WTP estimates for the unlabelled experiment.

	All	Infrequent/ Non-customers	Regular customers	Daily customers
Journey time (CDN$ per 10 minutes reduction)	$0.96	$1.35	$0.82	$0.85
Walking time (CDN$ per 5 minutes reduction)	$0.20	$0.53	$0.09	$0.12
Service headway (CDN$ per 5 minutes reduction)	$0.34	$0.33	$0.33	$0.37
Zero transfer (CDN$ per trip)	$2.69	$4.33	$2.36	$2.04
One transfer (CDN$ per trip)	$1.89	$2.71	$1.65	$1.64
Real-time info. At-stop (CDN$ per trip)	$0.59	$0.41	$0.55	$0.68
Real-time info. On-board (CDN$ per trip)	$0.89	$0.93	$0.88	$0.88

Red cells refer to lower WTP and Green cells refer to higher WTP.

4.6. HSR routes legacy

Respecting the legacy of HSR routes is essential for building transit ridership as it is highly influenced by residents' familiarity with the transit system. In this respect, HSR staff completed questionnaires to develop HSR Legacy Q-Cards. Those Q-cards include, among other points, historical perspective, major attractions, interlining, and last performed intervention. Those Q-Cards, as shown in Figure 4-6, are an excellent source for steering network reconfiguration while preserving HSR routes legacy.



If yes, please provide more details

8. Timed Transfer
Yes ☐ No ☐
If yes, please provide more details (e.g. routes/stations)

9. Meets productivity targets
Yes ☐ No ☐
Weekday Peak average off-peak average
Weekend Peak average off-peak average

10. Adherence to schedule
Weekdays High ☐ Moderate ☐ Low ☐
Saturday High ☐ Moderate ☐ Low ☐
Sunday High ☐ Moderate ☐ Low ☐

11. Requires intervention
Yes ☐ No ☐

12. Urgency of interventions
High ☐ Moderate ☐ Low ☐

13. Required interventions
Route reconfiguration ☐
Change of vehicle type ☐
Change of frequency/headway ☐
Change of service hours ☐
Please describe

14. Other comments related to the route are more than welcomed ☺

1. Route Name & ID
2. Historical Perspective
3. Major trip attractions/generations land uses
Attractions
Generations
4. Peak demand
Am Inbound ☐ Am Outbound ☐
Pm Inbound ☐ Pm Outbound ☐
Am General ☐ Pm General ☐
5. Others, please explain
6. Recent modifications/pilots in the last 4 years
Yes ☐ No ☐
If yes, list the types of modifications (e.g. frequency, service hours, route reconfiguration, other)
If yes, list the reasons for modifications (e.g. users demand, policy, planned expansion)
7. Interlined
Yes ☐ No ☐

Figure 4-6: A template of HSR Routes Q-Cards

4.7. Land uses

As the effectiveness of any urban transit systems depends mainly on the integration between public transit and land use. The existing and planned land uses for the City of Hamilton were considered in the network reconfiguration. The importance of each land use reflects how supportive this land use to transit service (i.e., the anticipated travel demand), which was determined based on best practices and supported through workshops with HSR personnel. The importance of land use, from a transit perspective, were modelled to justify the allocation of transit services. Figure 4-7 shows the importance of the land uses for the City of Hamilton from a transit perspective.

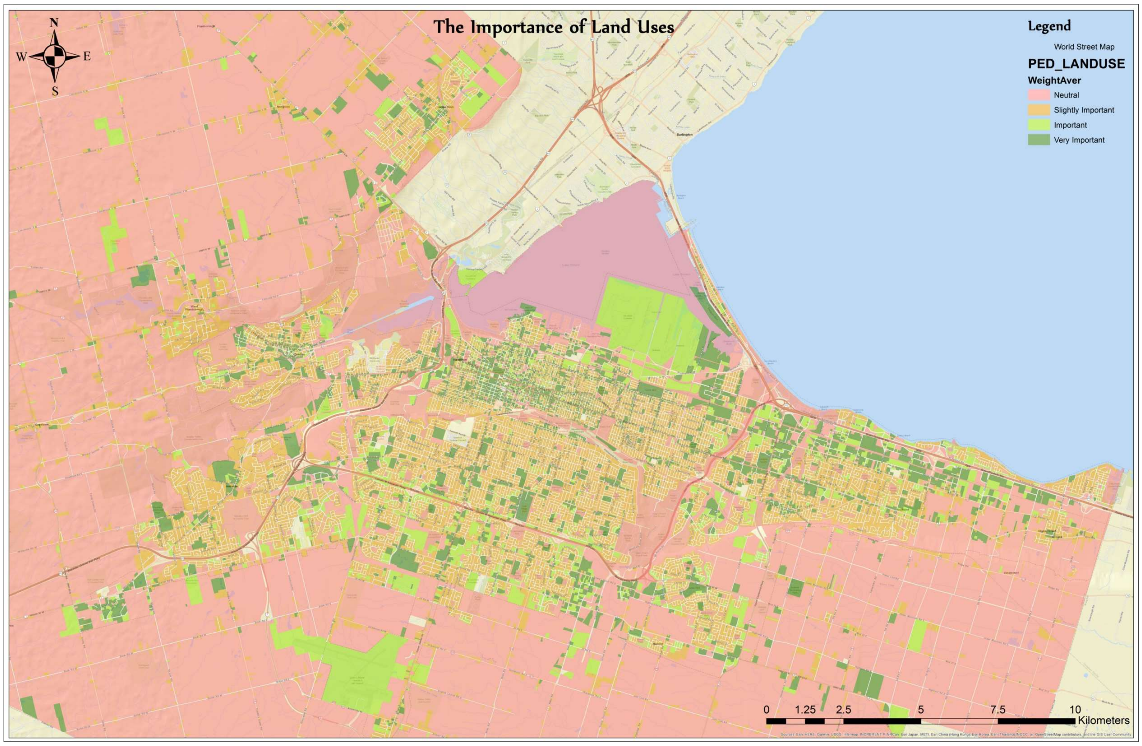


Figure 4-7: The importance of land uses from a transit perspective.

CHAPTER 5

ROUTE-SPECIFIC RECONFIGURATION

5. Route-Specific Reconfiguration

This chapter illustrates the proposed network reconfiguration at the route level. The reconfigured routes are assigned to one of the following five categories: Bus Rapid Transit, Express, Collectors, Local, and Regional routes. Each category represents a distinct operation profile.

As outlined in Chapter 2, the five categories are grounded on the total-trip concept for the proposed network and could be seen in a hierarchical arrangement, where the proposed BRT is the apex of the hierarchy. That said, each existing route is presented side-by-side with the reconfigured service to ease comparison.

5.1. Express Services

As outlined in Chapter 2, connecting HSR hubs without transfers is one of the main planning objectives derived from the analysis. The proposed eight express routes will enable hub-to-hub direct and fast trips. The service is proposed to operate all week with frequencies ranging from 6-12 buses per hour (5-10 mins headway). In addition, a stop rationalization analysis is required to eliminate the need for frequent stopping on express routes. The proposed express routes will replace existing (not necessarily express) routes as detailed in the following subsections.

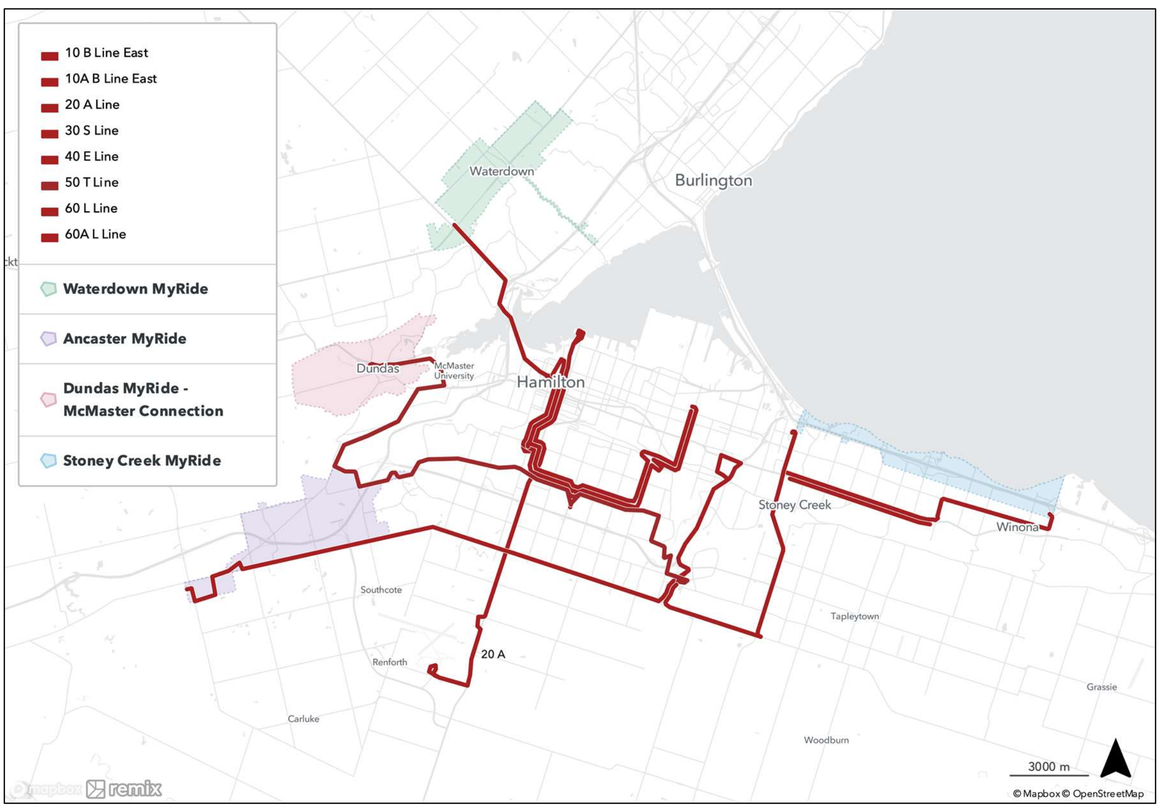


Figure 5-1: Proposed Express Routes (n=8)

Express Route – 10 B Line East Express

This is a Rapid transit route that travels from Eastgate Square Terminal in the west to Winona Crossing Terminal in the east, via Queenston Rd/Highway 8, Jones Rd, Stoney Creek Gateway, and Barton St E. Service would run seven days a week, and the route serves around 19,500 population within 400 m of proposed stops. Figure 5-2 shows the proposed alignment of Route 10 B Line East.

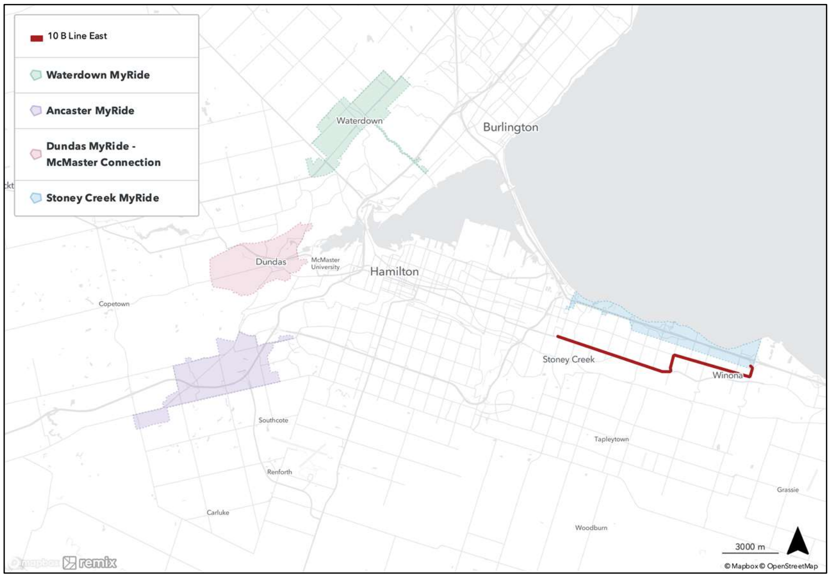


Figure 5-2: The proposed alignment of route 10 B East (Express)

Express Route – 10 B A Line East Express

This is a Rapid transit route that travels from Eastgate Square Terminal in the west to Stoney Creek Gateway in the east, via Queenston Rd/Highway 8. This route is intended to increase frequency along the Queenston Rd/Highway 8 corridor between Eastgate and Stoney Creek Gateway, where demand will be highest. Service would run seven days a week, and the route serves around 15,100 population within 400 m of proposed stops. Figure 5-3 shows the proposed alignment of Route 10A B Line East.

Figure 5-3: The proposed alignment of route 10 B A East (Express)

Express Route – 20 A Express

This is a Rapid transit route that travels from Hamilton International Airport in the south to the Pier 8 Waterfront in the north, via Upper James, Mohawk College Terminal, James St, and Downtown Hamilton. Service would run seven days a week, and the route serves around 22,800 population within 400 m of proposed stops. Figure 5-4 shows the proposed alignment of Route 20 A Line.

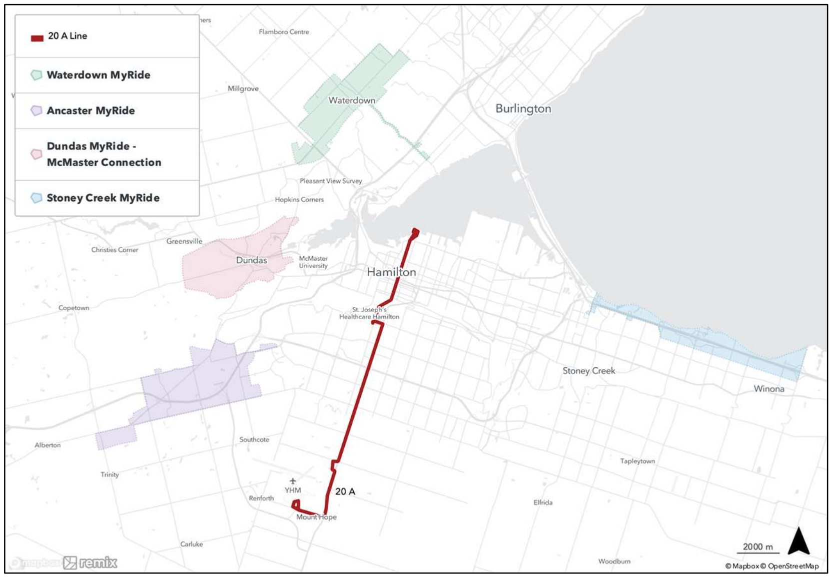


Figure 5-4: The proposed alignment of route 20 A (Express)

Express Route – 30 S Express

This is a Rapid transit route that travels from Ancaster Fairgrounds Gateway in the west to Parkdale Terminal in the east, via Garner Rd/Rymal Rd, Heritage Greene Terminal, and the Red Hill Valley Parkway. Service would run seven days a week, and the route serves around 20,900 population within 400 m of proposed stops. Figure 5-5 shows the proposed alignment of Route 30 S Line.

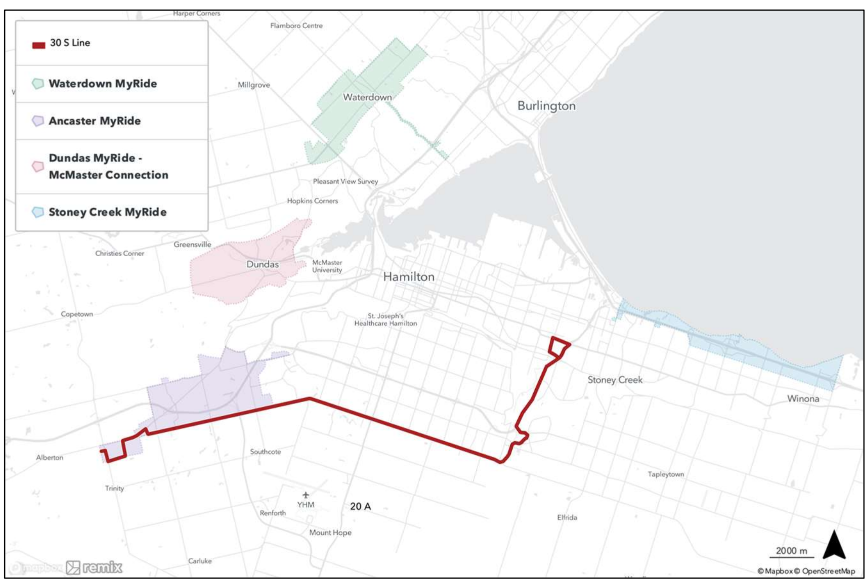


Figure 5-5: The proposed alignment of route 30 S (Express)

Express Route – 40 E Express

This is a Rapid transit route that travels from Heritage Greene Terminal in the south to Confederation GO Station in the north, via Rymal Rd E, Elfrida Gateway, Upper Centennial Pkwy, Eastgate Square Terminal, and Centennial Pkwy. Service would run seven days a week, and the route serves around 10,400 population within 400 m of proposed stops. Figure 5-6 shows the proposed alignment of Route 40 E Line.

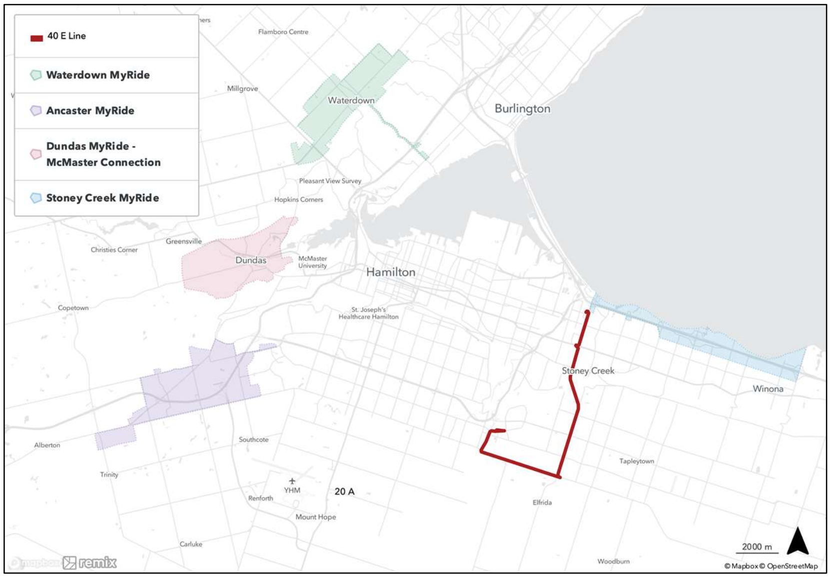


Figure 5-6: The proposed alignment of route 40 E (Express)

Express Route – 50 T Express

This is a Rapid transit route that travels from Downtown Dundas Terminal in the west to Heritage Greene Terminal in the east, via Cootes Dr, Main St W/Wilson St E, Golf Links Rd, Meadowlands Terminal, Mohawk Rd, CF Lime Ridge Terminal, and Upper Kenilworth Ave. Service would run seven days a week, and the route serves around 37,700 population within 400 m of proposed stops. Figure 5-7 shows the proposed alignment of Route 50 T Line.

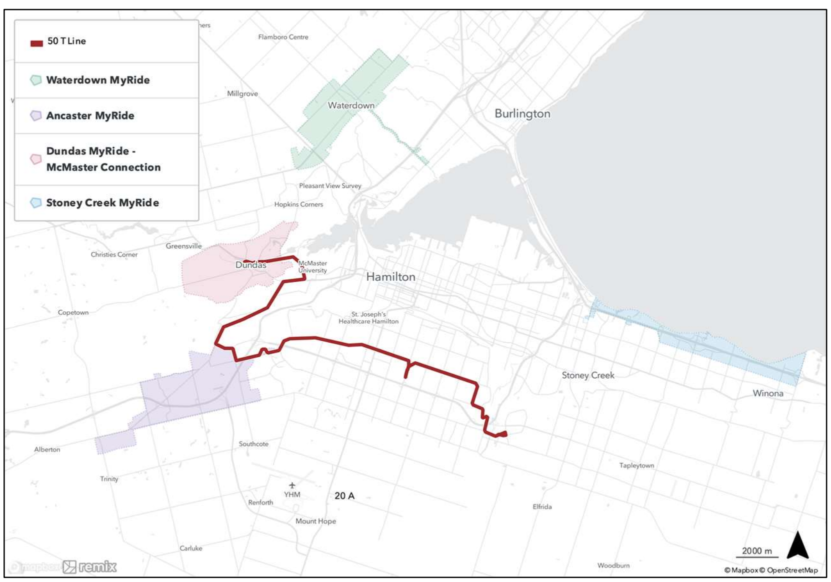


Figure 5-7: The proposed alignment of route 50 T (Express)

Express Route – 60 L Express

This is a Rapid transit route that travels from Waterdown Gateway in the west to Centre Mall Terminal in the east, via Highway 6, Highway 403, York Blvd, James St, Downtown Hamilton, Mohawk College Terminal, Upper James St, Mohawk Rd E, CF Lime Ridge Terminal, Upper Ottawa St, and Kenilworth Ave. In addition to providing a direct connection to Waterdown from Downtown Hamilton, this route increases the frequency along the busiest sections of the A and T Line corridors. Service would run seven days a week, and the route serves around 43,800 population within 400 m of proposed stops. Figure 5-8shows the proposed alignment of Route 60 L Line.

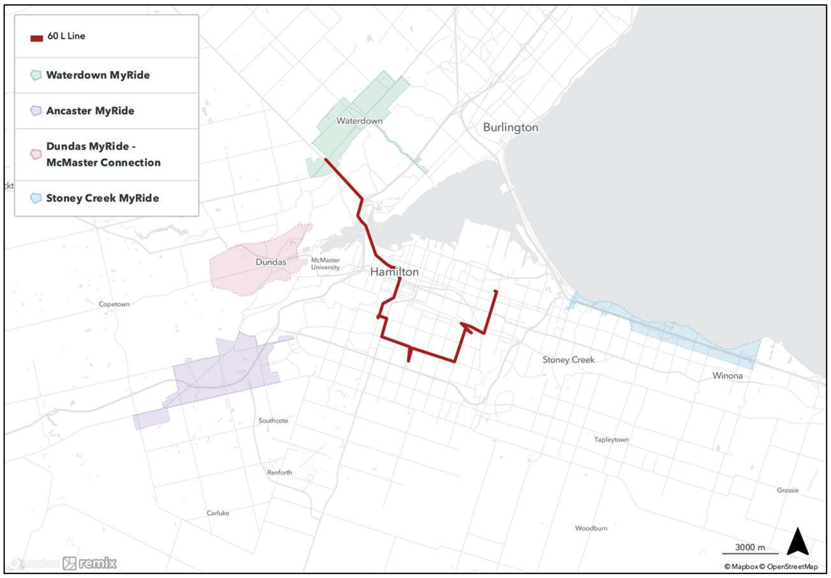


Figure 5-8: The proposed alignment of route 60 L (Express)

Express Route – 60A L Express

This is a Rapid transit route that travels from West Harbour GO Station in the west to Centre Mall Terminal in the east, via James St, Downtown Hamilton, Mohawk College Terminal, Upper James St, Mohawk Rd E, CF Lime Ridge Terminal, Upper Ottawa St, and Kenilworth Ave. This route increases the frequency along the busiest sections of the A and T Line corridors. Service would run seven days a week, and the route serves around 41,200 population within 400 m of proposed stops. Figure 5-9 shows the proposed alignment of Route 60A L Line.

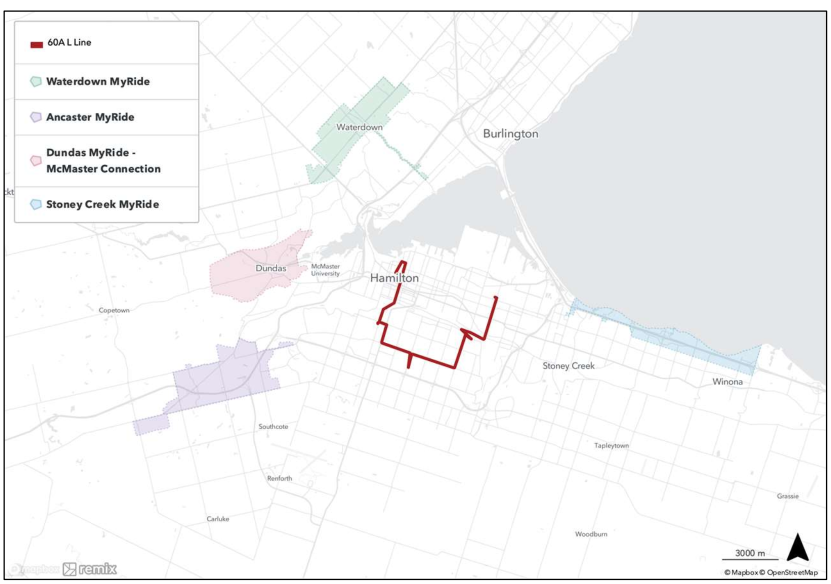


Figure 5-9: The proposed alignment of route 60A L (Express)

5.2. Collectors

Collectors are the dominant route category in the service (16 routes). Similar to express services, these routes provide hub-to-hub connectivity. However, they offer relatively a higher level of coverage (spatially) and more stops. The proposed collector routes are presented in Figure 5-10.The frequency of the collector routes range between 2-4 buses per hour (15-30 mins headway).

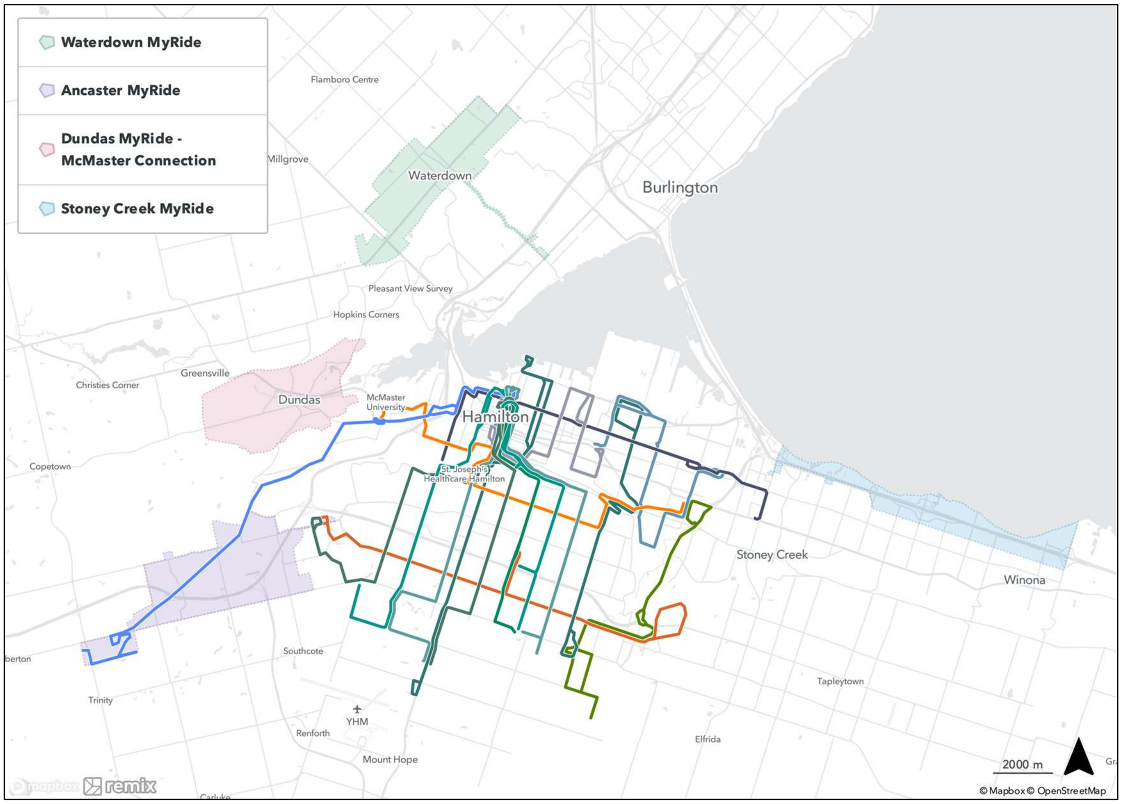


Figure 5-10: Proposed Collectors routes (n=16)

5.2.1. Proposed Collectors East-West

A total of six East-West (Figure 5-11) collector routes are proposed. The frequency of each route is informed by the demand observed from the current operation, in addition to the data outlined in Chapter 2.

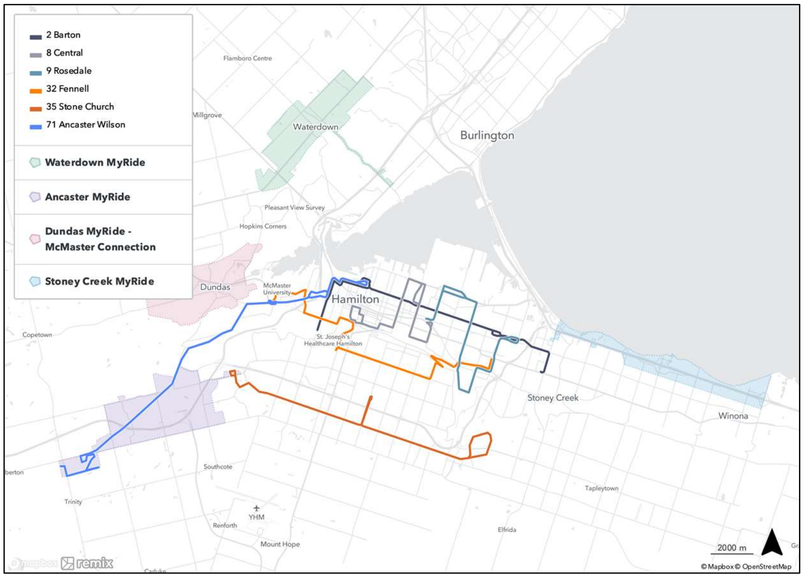


Figure 5-11: Proposed Collectors Routes (East-West)

Route – 2 Barton

This is a Collector transit route that travels from downtown Hamilton to Stoney Creek Hub (Eastgate square mall) in the east through Barton Street. Service would run seven days a week, and the route serves around 44,100 population within 400 m of proposed stops.

Route – 8 Central

This is a Core transit route that travels from Hamilton GO Centre in the west to Scott Park LRT Station in the east, via Bay St, Charlton Ave, Stinson St, Wentworth St, Burlington St, Birch Ave & Sherman Ave, Cumberland St, and Gage Ave. The primary purpose of the route is to act as a feeder to the LRT line, running in a 'zig zag' pattern through the Lower City. The route intersects the LRT at multiple stations, allowing for transfer opportunities between the two. Service would run seven days a week, and the route serves around 47,900 population within 400 m of proposed stops.

Route – 9 Rosedale

This is a Core transit route that travels from Scott Park LRT station in the west to Parkdale Terminal in the east, via Gage Ave, Burlington St, Kenilworth Ave, Centre Mall Terminal, Kimberly Dr, Greenhill Ave, Cochrane Rd, King St, Parkdale Ave, Barton St, and Melvin Ave. Like the Route 8 Central, the primary purpose of this route is to act as a feeder to the LRT line. Routes 8 Central and 9 Rosedale can be operated as a single through service, or independently, depending on operational preferences. Service would run seven days a week, and the route serves around 31,000 population within 400 m of proposed stops.

Route – 32 Fennell

This is a Core transit route that travels from McMaster University Terminal in the west to Parkdale Terminal in the east, via Sterling St, Longwood Rd, Aberdeen Ave, Herkimer St and Charlton Ave, James Mountain Rd, Mohawk College Terminal, Fennell Ave, Kenilworth Access, King St, and Parkdale Ave. This route provides a direct connection between McMaster University, the McMaster Innovation Park, and Mohawk College. Service would run seven days a week, and the route serves around 44,700 population within 400 m of proposed stops.

Route – 35 Stone Church
This is a Core transit route that travels from Meadowlands Terminal in the west to Valley Park Loop in the east, via Cloverleaf Dr, Stonehenge Dr, Stone Church Rd, CF Lime Ridge Terminal, Heritage Greene Terminal, and Paramount Dr. The route intersects the LRT at multiple stations, allowing for transfer opportunities between the two. Service would run seven days a week, and the route serves around 33,000 population within 400 m of proposed stops.

Route – 71 Ancaster Wilson
This is a Core transit route that travels from Ancaster Fairgrounds Gateway in the west to the West Harbour GO Station in the east, via the Ancaster Business Park, Wilson St, Main St, McMaster University, Dundurn St, York Blvd, Locke St, and Barton St. This route provides a direct connection between Ancaster, McMaster University, and GO Transit's Lakeshore West line. Service would run seven days a week, and the route serves around 23,900 population within 400 m of proposed stops.

5.2.2. Proposed Collectors North-South

A total of nine collector routes are proposed along the North-South corridors, as illustrated in Figure 5-12.

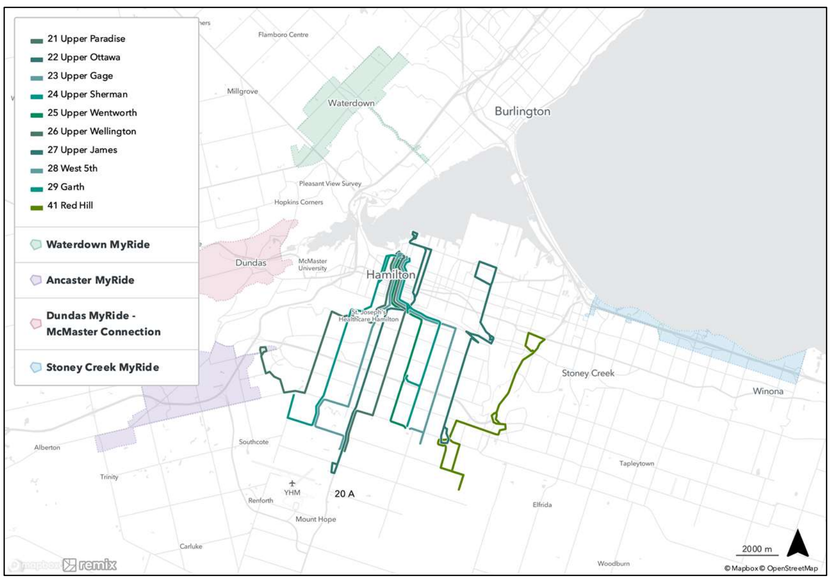


Figure 5-12: Proposed Collectors Routes (North-South)

Route – 21 Upper Paradise
This is a Core transit route that travels from Meadowlands Terminal in the south to West Harbour GO Station in the north, via Meadowlands Blvd, Raymond Rd, Rymal Rd, Upper Paradise Rd, Scenic Dr, Fennell Ave, Mohawk College Terminal, James Mountain Rd, James St. Service would run seven days a week, and the route serves around 34,500 population within 400 m of proposed stops.

Route – 22 Upper Ottawa
This is a Core transit route that travels from Upper Ottawa & Rymal in the south to Industrial & Depew in the north, via Upper Ottawa St, Kenilworth Access, and Ottawa St. This route also has a direct connection to Route 41 Red Hill for trips into the Red Hill Industrial Park. Service would run seven days a week, and the route serves around 24,600 population within 400 m of proposed stops.

Route – 23 Upper Gage
This is a Core transit route that travels from Upper Sherman Loop in the south to West Harbour GO Station in the north, via Upper Sherman Ave, Rymal Rd, Upper Gage Ave, Concession St, Jolley Cut, and James St. Service would run seven days a week, and the route serves around 43,600 population within 400 m of proposed stops.

Route – 24 Upper Sherman
This is a Core transit route that travels from Upper Sherman Loop in the south to West Harbour GO Station in the north, via Upper Sherman Ave, Limeridge Rd, CF Lime Ridge Terminal, Concession St, Jolley Cut, and James St. Service would run seven days a week, and the route serves around 38,200 population within 400 m of proposed stops.

Route – 25 Upper Wentworth
This is a Core transit route that travels from Upper Sherman Loop in the south to West Harbour GO Station in the north, via Upper Sherman Ave, Rymal Rd, Upper Wentworth St, CF Lime Ridge Terminal, Concession St, Jolley Cut, and James St. Service would run seven days a week, and the route serves around 35,100 population within 400 m of proposed stops.

Route – 26 Upper Wellington
This is a Core transit route that travels from the Mountain Transit Centre in the south to West Harbour GO Station in the north, via Upper James St, Rymal Rd, Upper Wellington St, Jolley Cut, and James St. Service would run seven days a week, and the route serves around 33,600 population within 400 m of proposed stops.

Route – 27 Upper James
This is a Core transit route that travels from the Mountain Transit Centre in the south to West Harbour GO Station in the north, via Upper James St, Rymal Rd, Upper Wellington St, Jolley Cut, and James St. Service would run seven days a week, and the route serves around 27,300 population within 400 m of proposed stops.

Route – 28 West 5th
This is a Core transit route that travels from the Mountain Transit Centre in the south to West Harbour GO Station in the north, via Upper James St, Twenty Rd, Garth St, Rymal Rd, West 5th St, Mohawk College Terminal, James Mountain Rd, and James St. Service would run seven days a week, and the route serves around 28,200 population within 400 m of proposed stops.

Route – 29 Garth
This is a Core transit route that travels from Glancaster Loop in the south to West Harbour GO Station in the north, via Glancaster Rd, Twenty Rd, Garth St, Beckett Dr, Queen St and Hess St, and Stuart St. Service would run seven days a week, and the route serves around 34,200 population within 400 m of proposed stops.

Route – 41 Red Hill
This is a Core transit route that travels from Upper Ottawa & Rymal in the south to Parkdale Terminal in the north, via Glover Rd, Twenty Rd, Nebo Rd and Dartnall Rd, Stone Church Rd, Heritage Greene Terminal, and the Red Hill Valley Pkwy. This route provides a direct connection between the LRT and the Red Hill Business Park. Service would run seven days a week, and the route serves around 7,400 population within 400 m of proposed stops.

5.3. Local Routes

Local routes are the main feeders to proposed HSR hubs, collectors, express routes as well as the LRT. The main aim of each local route is to increase the service accessibility at the first/last mile operation. Therefore, the proposed local routes operate at a minimum frequency of two buses per hour, which increases to three buses per hour during the peak periods. Essentially, the proposed local routes are developed to provide full-service coverage around each HSR hub. A total of 13 local routes are developed in the proposed network, as detailed in Figure 5-13.

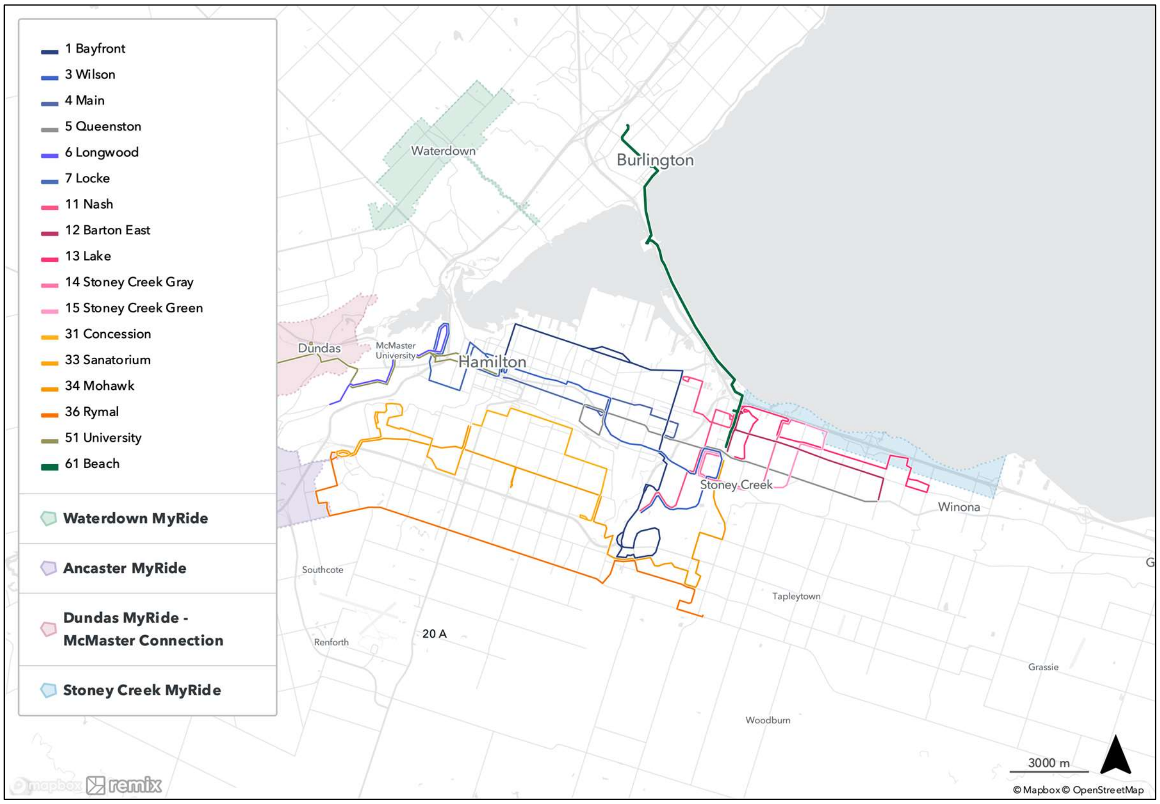


Figure 5-13: The proposed Local Routes (n=16)

Route – 1 Bayfront

This is a Local transit route that travels from Hamilton GO Centre in the west to Heritage Greene in the east, via James St, Downtown Hamilton, Burlington St, Parkdale Ave, Mount Albion Rd, the Red Hill Valley Pkwy, and Paramount Dr. Service would run seven days a week, and the route serves around 31,400 population within 400 m of proposed stops.

Route – 3 Wilson

This is a Local transit route that travels from Hamilton GO Centre in the west to Mount Albion Loop in the east, via John St and James St, Wilson St, Cannon St, Ottawa St, King St, Nash Rd, Queenston Rd, Centennial Pkwy, and Greenhill Ave. Service would run seven days a week, and the route serves around 57,700 population within 400 m of proposed stops.

Route – 4 Main

This is a Local transit route that travels from Hamilton GO Centre in the west to Parkdale Terminal in the east, via John St and James St, Main St, Ottawa St, Cannon St, Britannia Ave, Reid Ave, and Queenston Rd. Routes 3 Wilson and 4 Main run parallel to the LRT corridor through Central Hamilton and crossing each other at Ottawa St to provide a mid-route connection to the LRT at Ottawa Station. Service would run seven days a week, and the route serves around 42,800 population within 400 m of proposed stops.

Route - 5 Queenston
This is a Local transit route that travels from Gage Park Lay-By in the west to Stoney Creek Gateway in the east, via Ottawa St, Lawrence Rd, Gage Ave, Main St, Queenston Rd, Parkdale Terminal, Eastgate Square Terminal, and Highway 8. Route 5 provides local service along the LRT corridor between the Delta and Eastgate Square Terminal and provides local service along the B Line East corridor between Eastgate Square and Stoney Creek Gateway. Service would run seven days a week, and the route serves around 36,600 population within 400 m of proposed stops.

Route – 6 Longwood
This is a Local transit route that travels from West Hamilton Loop in the west to Princess Point Loop in the east, via Main St, Whitney Ave, Emerson Ave, McMaster University, Sterling St, King St, and Longwood Rd and Macklin St. This route provides a direct connection to McMaster University and Westdale for students who live in the western end of Hamilton. Service would run seven days a week, and the route serves around 10,600 population within 400 m of proposed stops.

Route – 7 Locke
This is a Local transit route that travels from Princess Point Loop in the west to Strathcona Loop in the east, via Macklin St and Longwood Rd, Aberdeen Ave, Locke St, Main St, James St, James LRT Station, York Blvd and Cannon St, Locke St, and Strathcona Ave. This route connects the western end of Central Hamilton with Downtown. Service would run seven days a week, and the route serves around 28,800 population within 400 m of proposed stops.

Route – 11 Nash
This is a Local transit route that travels from Mount Albion Loop in the south to Parkdale & Mead in the north, via Mount Albion Rd, Greenhill Ave, Quigley Rd, Nash Rd, Bancroft Rd, Centennial Pkwy, Confederation GO Station, Barton St, Woodward Ave, and Glow Ave. This route connects the western end of Central Hamilton with Downtown. Service would run seven days a week, and the route serves around 19,700 population within 400 m of proposed stops.

Route – 12 Barton East
This is a Local route that travels from Eastgate Square Terminal in the west to Stoney Creek Gateway in the east, via Centennial Pkwy, Confederation Walmart, Barton St, and Jones Rd. Customers can access Confederation GO from Centennial Pkwy. Service would run seven days a week, and the route serves around 13,700 population within 400 m of proposed stops.

Route – 13 Lake
This is a Local route that travels from Eastgate Square Terminal in the west to 930 Arvin in the east, via Queenston Rd, Lake Ave, Confederation Walmart, South Service Rd, Grays Rd, and Arvin Ave. This route connects Eastgate Square Terminal with the Stoney Creek industrial areas north of Barton St. Service would run seven days a week, and the route serves around 12,100 population within 400 m of proposed stops.

Route – 14 Stoney Creek Gray
This is a Local route that travels from Eastgate Square Terminal in the west to South Service & Green in the east, via Queenston Rd, Nash Rd, St. Joseph's Healthcare King Campus, King St, and Gray Rd. This

route is interlined with Route 15 Stoney Creek Green. Service would run seven days a week, and the route serves around 15,800 population within 400 m of proposed stops.

Route – 15 Stoney Creek Green
This is a Local route that travels from Eastgate Square Terminal in the west to South Service Rd & Green in the east, via Queenston Rd, Nash Rd, St. Joseph's Healthcare King Campus, King St, Green Rd, Arvin Ave, and Millen Rd. This route is interlined with Route 14 Stoney Creek Gray. Service would run seven days a week, and the route serves around 17,700 population within 400 m of proposed stops.

Route – 31 Concession
This is a Local route that travels from Mohawk College Terminal in the west to Limeridge & Lennox in the east, via Fennell Ave, Upper James St, Inverness Ave, Upper Wellington St, Concession St, Upper Gage Ave, Fennell Ave, and Upper Kenilworth Ave. This route is interlined with Route 33 Sanatorium. Service would run seven days a week, and the route serves around 26,300 population within 400 m of proposed stops.

Route – 33 Sanatorium
This is a Local route that travels from Meadowlands Terminal in the west to Mohawk College Terminal in the east, via Golf Links Rd, Mohawk Rd, Magnolia Dr, Scenic Dr, Redfern Ave, Chedmac Dr, Sanatorium Rd, Garth St, Limeridge Rd, and West 5th St. This route is interlined with Route 31 Concession. Service would run seven days a week, and the route serves around 22,900 population within 400 m of proposed stops.

Route – 34 Mohawk
This is a Local route that runs from Meadowlands Terminal in the west to Eastgate Square Terminal in the east, via Golf Links Rd, Mohawk Rd, West 5th St, Mohawk College Terminal, Upper Wentworth St, CF Lime Ridge Terminal, Upper Kenilworth Ave, Limeridge Rd, Mountain Brow Rd, Pritchard Rd, Stone Church Rd, Heritage Greene Terminal, Paramount Dr, Marston St, Gordon Drummond Ave, Isaac Brock Rd, First Rd, Highland Rd, Picardy St, Trafalgar Dr, Green Mountain Rd, and Centennial Pkwy. The segment from Meadowlands Terminal to Heritage Greene Terminal provides local service along the T Line corridor. Service would run seven days a week, and the route serves around 48,700 population within 400 m of proposed stops.

Route – 36 Rymal
This is a Local route that runs from Meadowlands Terminal in the west to Elfrida Gateway in the east, via Meadowlands Blvd, Stonehenge Dr, Kitty Murray Dr, Redeemer College University, Garner Rd, Rymal Rd, Upper Red Hill Pkwy, Stone Church Rd, Heritage Green Terminal, Winterberry Dr, Highland Rd, Highbury Dr, Whitedeer Rd, and Rymal Rd. The segment from Redeemer College University to Heritage Greene Terminal provides local service along the S Line corridor. Service would run seven days a week, and the route serves around 35,200 population within 400 m of proposed stops.

Route – 51 University
This is a Local route that runs from Governors & Pirie in the west to Hamilton GO Centre in the east, via Governors Rd, Downtown Dundas Terminal, Ogilvie Rd, South St, Osler Dr, Main St, Whitney Ave, Emerson Ave, McMaster University, Sterling St, King St, and Main St. Service would run seven days a week, and the route serves around 35,600 population within 400 m of proposed stops.

Route Local – 61 Beach

This is a Local route that runs from Eastgate Square Terminal in the south to Burlington GO Station in the north, via Centennial Pkwy, Confederation GO Station, Van Wagners Beach Rd, Beach Blvd, Eastport Dr, the Canada Centre for Inland Waters (CCIW), Lakeshore Rd, Downtown Burlington Terminal, Brant St, and Fairview St. This route provides a connection between the east end of Hamilton, Stoney Creek, and Burlington. Service would run seven days a week, and the route serves around 16,300 population within 400 m of proposed stops.

5.4. Overview of the proposed network

In addition, Table 5-1 provides a side-by-side comparison between the current HSR network and the proposed reconfiguration with respect to the service frequency from 5:00 to 26:00 on weekdays. Similarly, Table 5-2 and Table 5-3 display the same comparison for the Saturday and Sunday respectively.

The data clearly demonstrates the superior performance of the proposed network in terms of spatial coverage, temporal accessibility, and connectivity.

Table 5-1: Comparison of current and proposed HSR networks (frequency - Weekdays)

<table>
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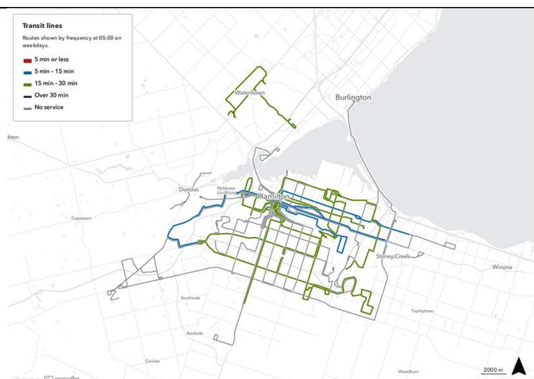
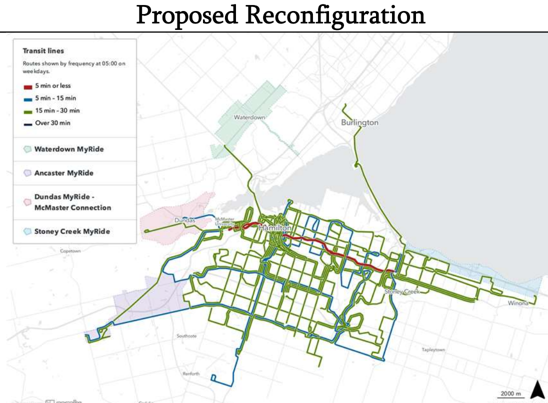
<tr><td>05:00</td><td>
</td><td>
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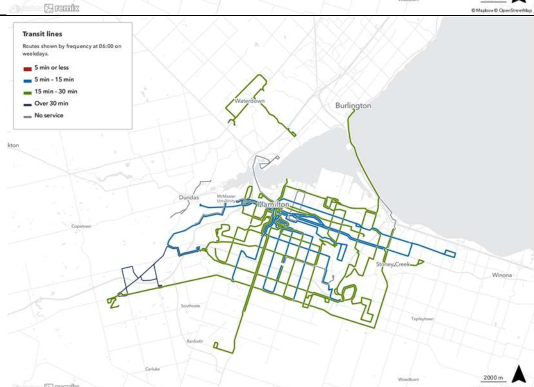
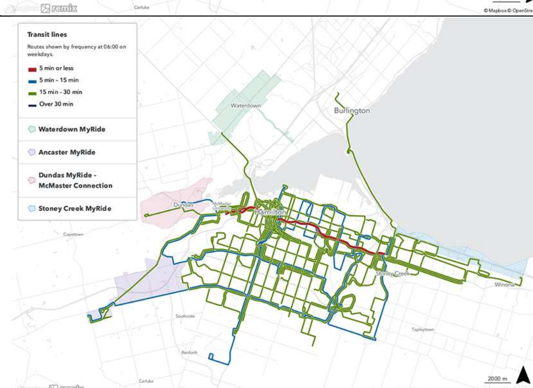
<tr><td>06:00</td><td>
</td><td>
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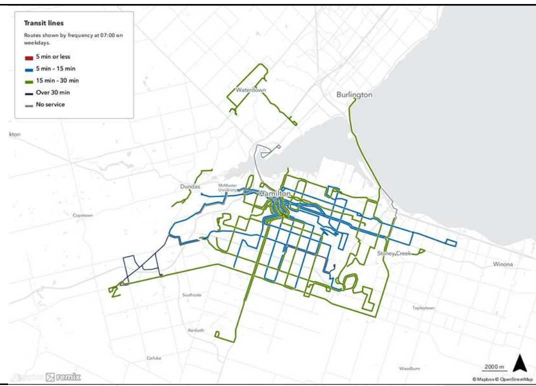
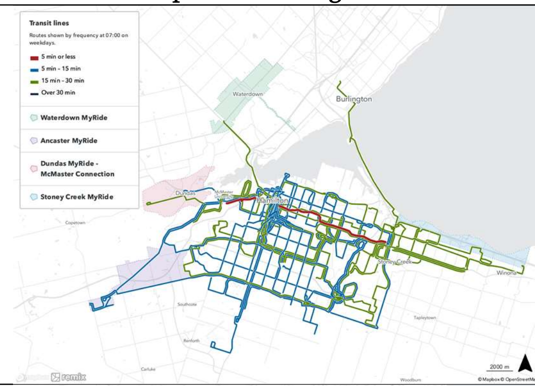
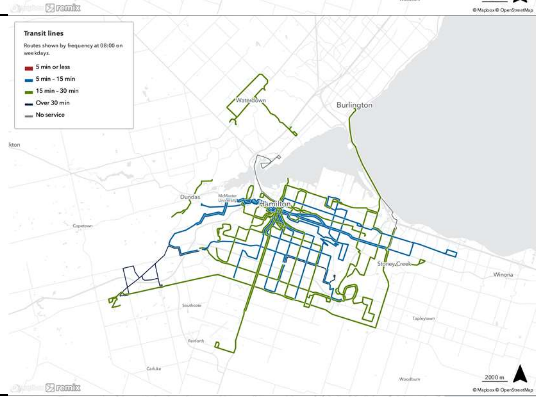
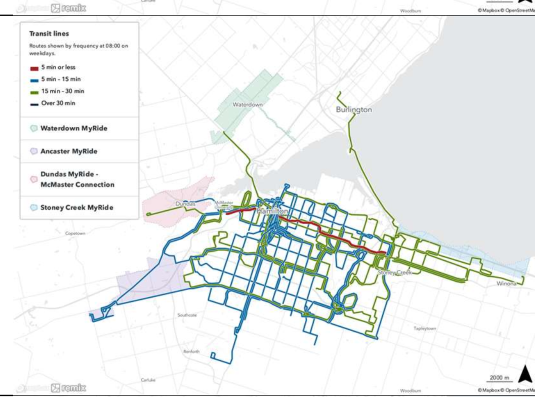
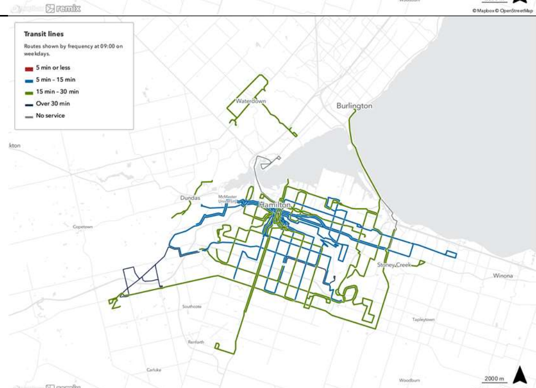
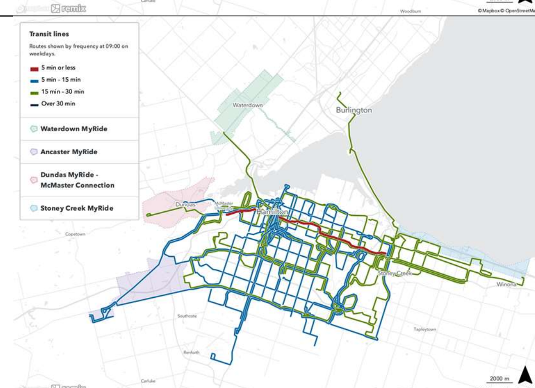
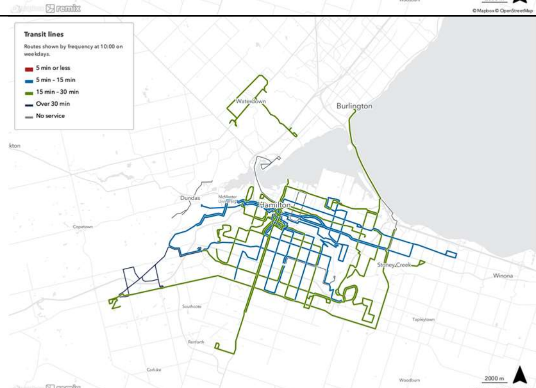
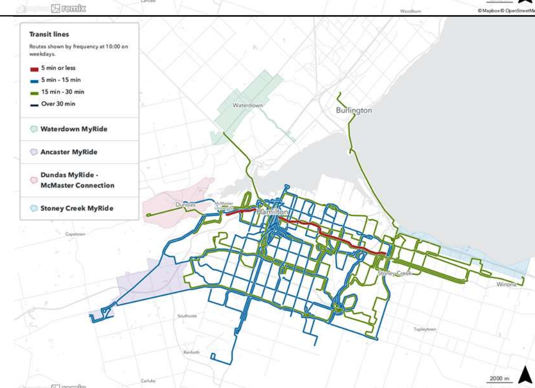
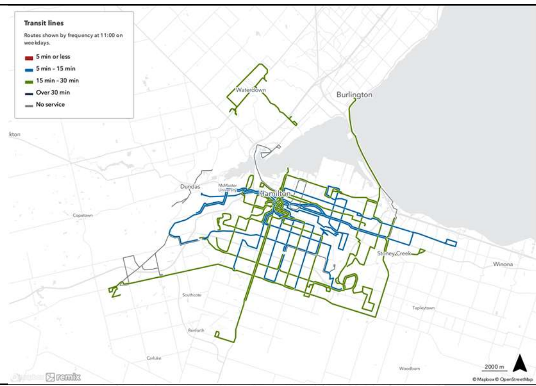
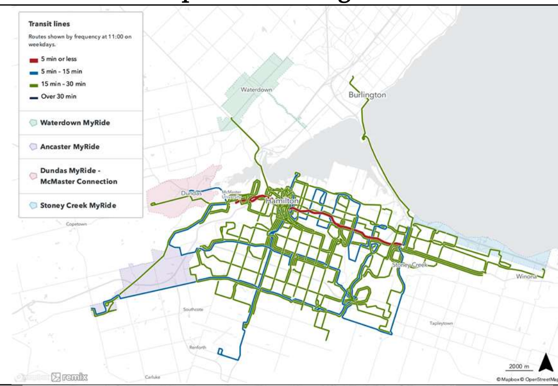
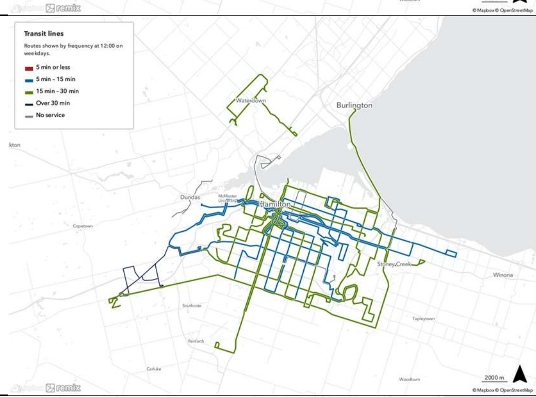
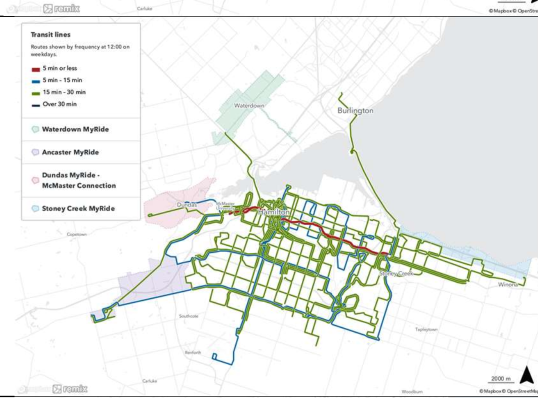
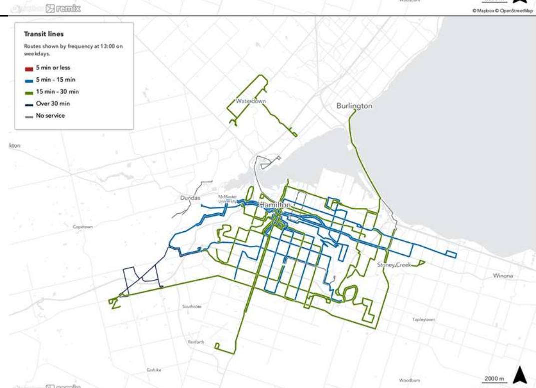
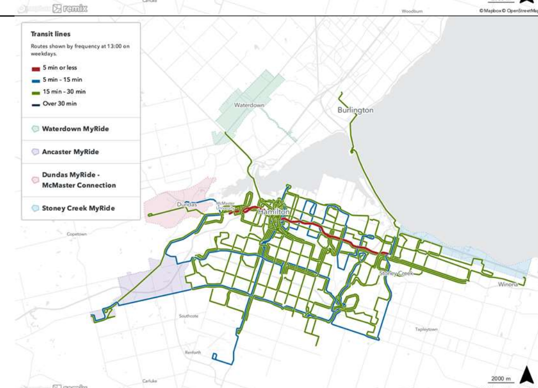
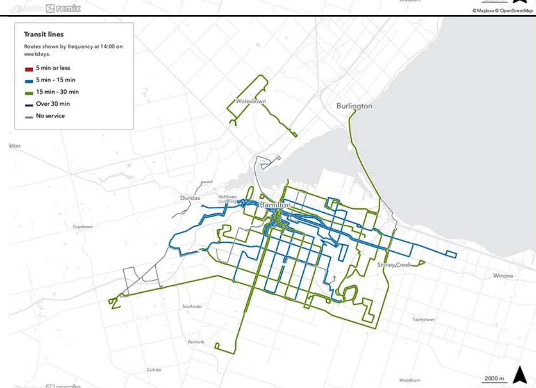
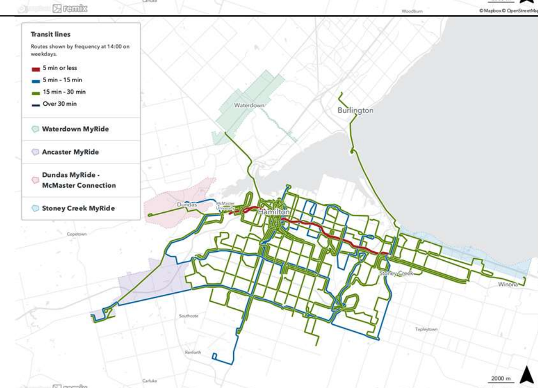
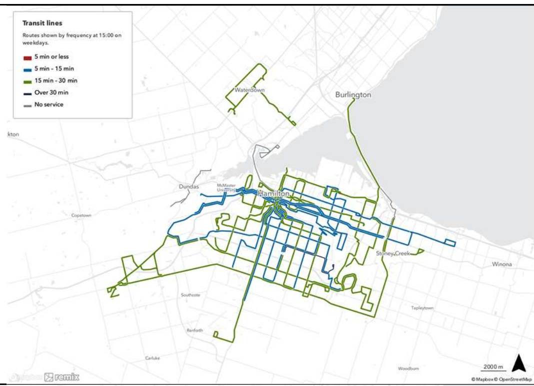
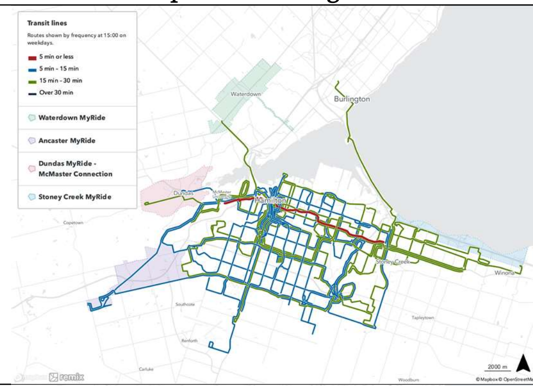
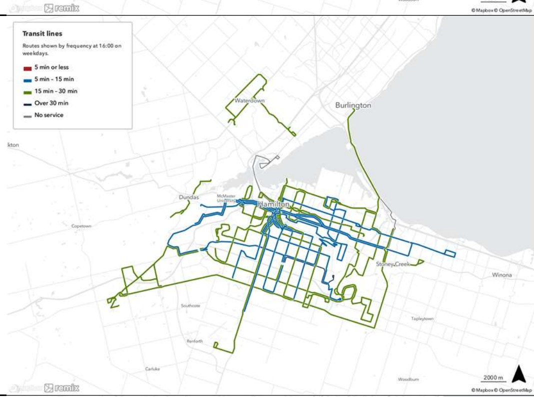
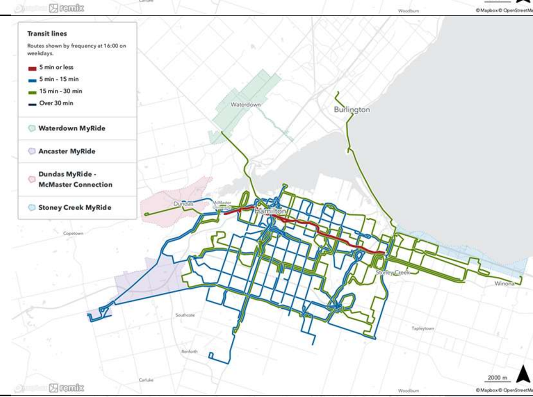
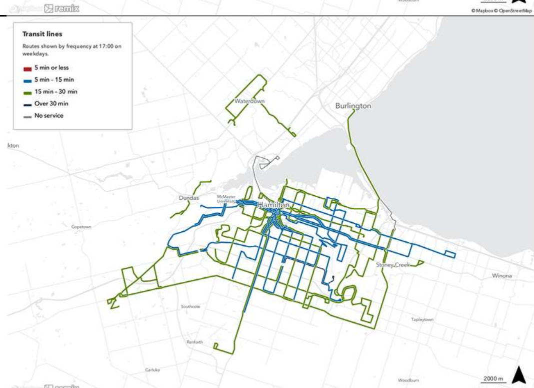
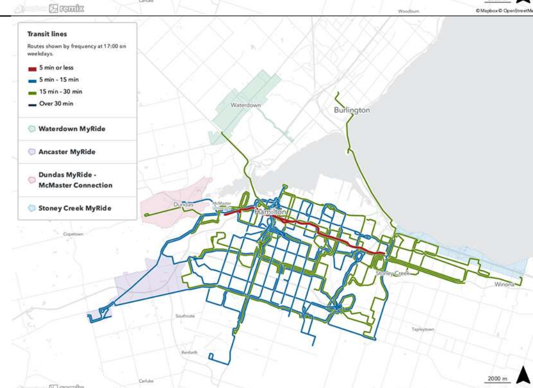
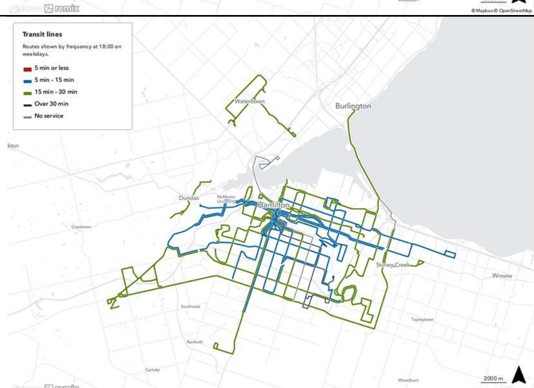
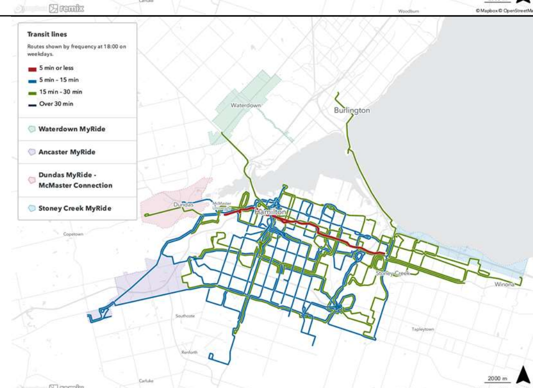
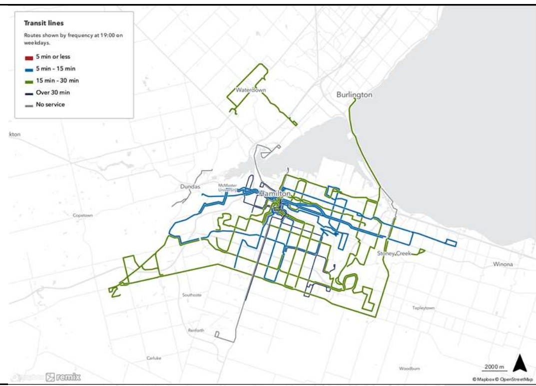
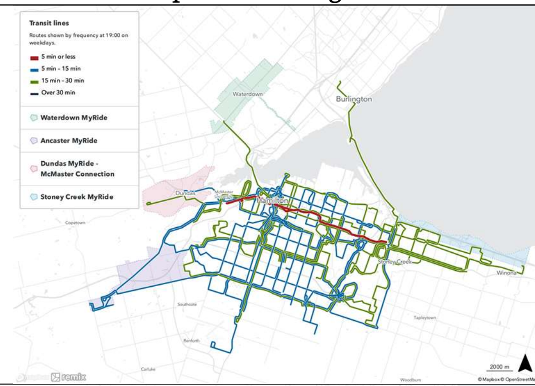
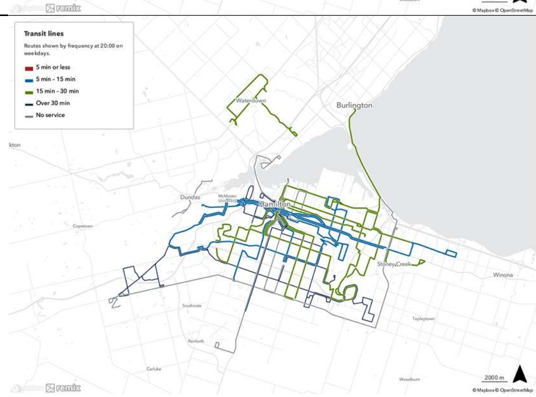
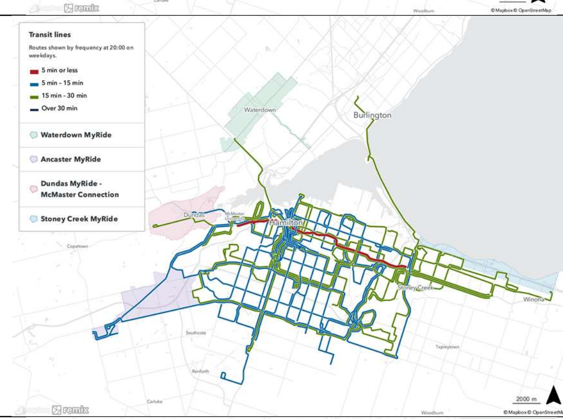
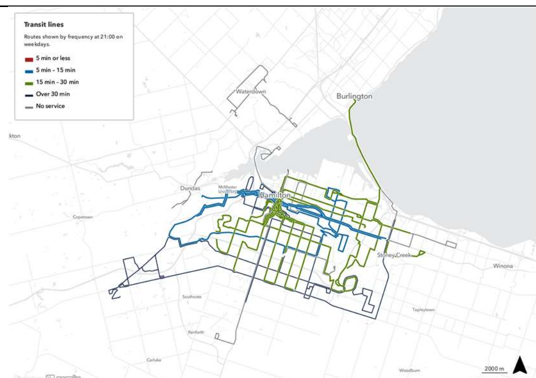
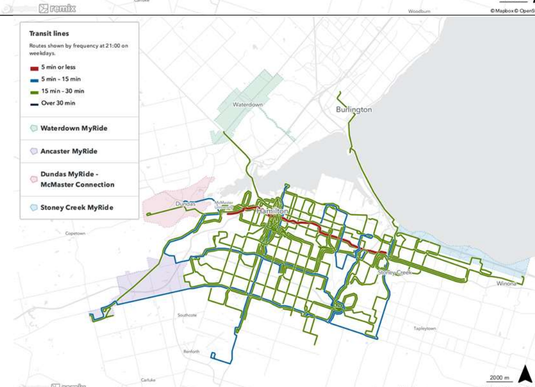
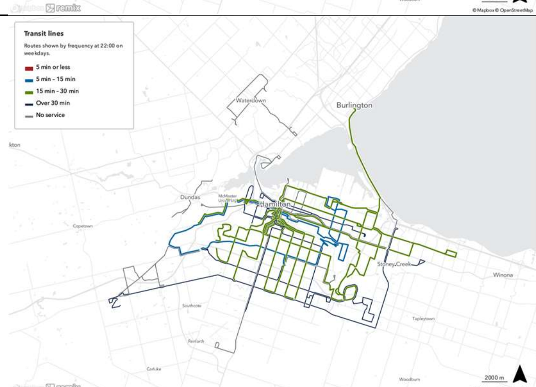
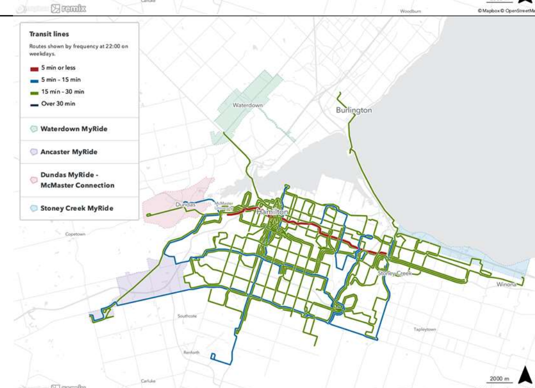
Time	Current HSR Network	Proposed Reconfiguration
07:00		
08:00		
09:00		
10:00		

Time	Current HSR Network	Proposed Reconfiguration
11:00		
12:00		
13:00		
14:00		

Time	Current HSR Network	Proposed Reconfiguration
15:00		
16:00		
17:00		
18:00		

Time	Current HSR Network	Proposed Reconfiguration
19:00		
20:00		
21:00		
22:00		

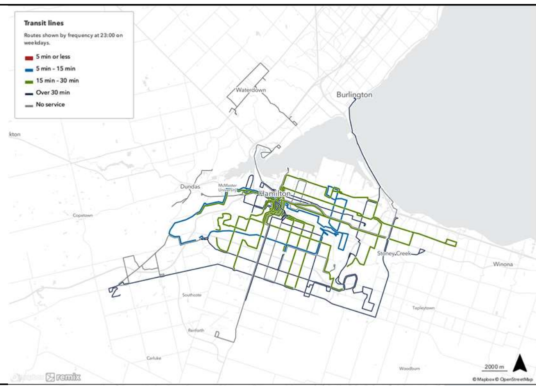
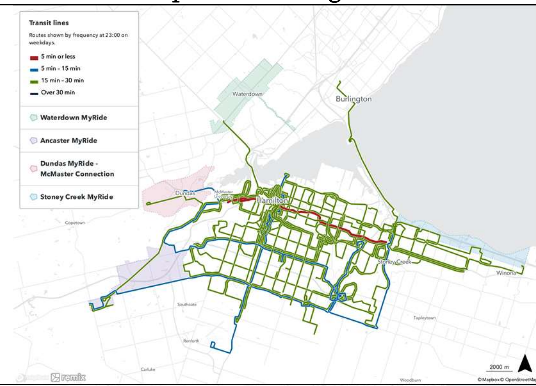
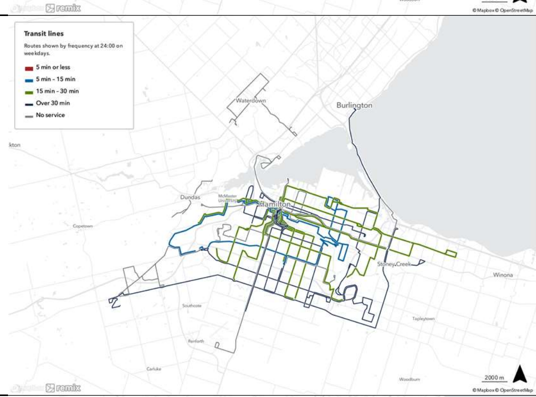
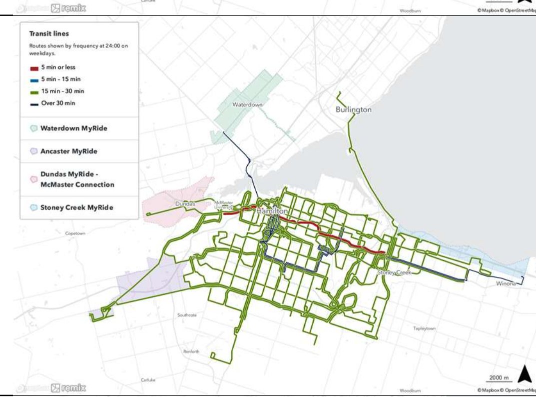
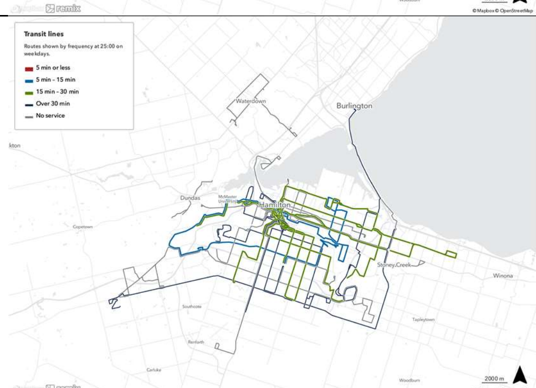
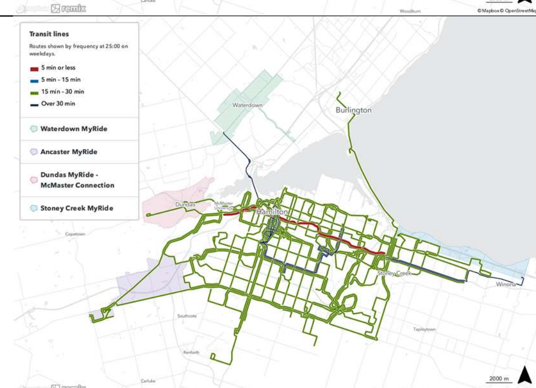
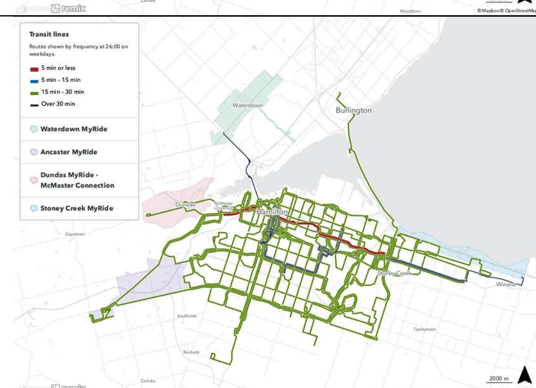
Time	Current HSR Network	Proposed Reconfiguration
23:00		
24:00		
25:00		
26:00		

Table 5-2: Comparison of current and proposed HSR networks (frequency - Saturday)

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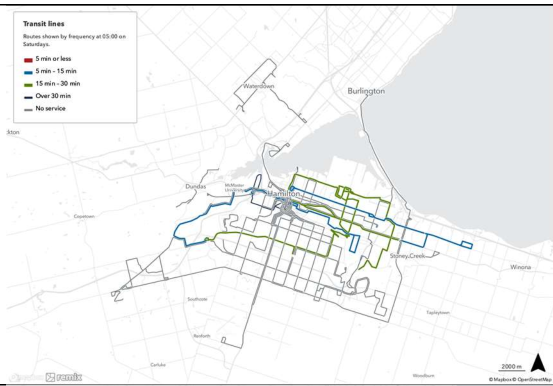
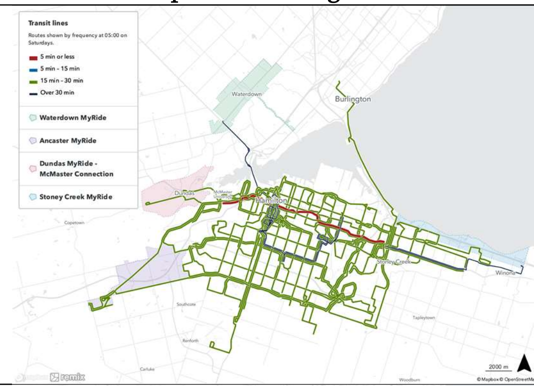
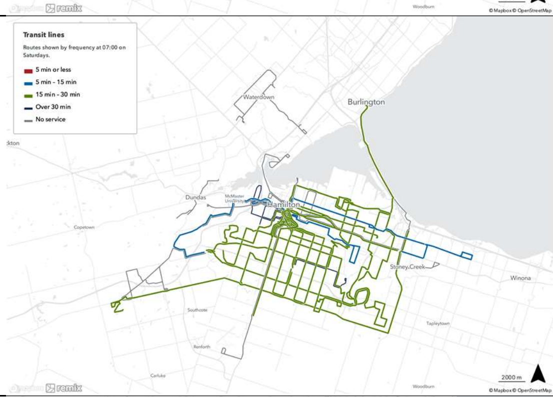
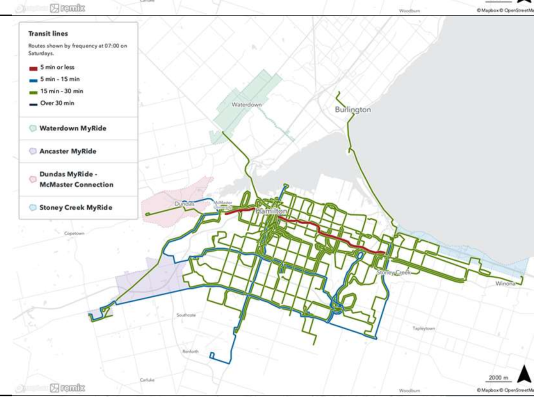
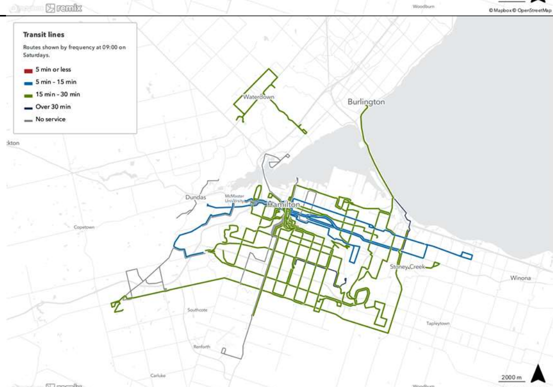
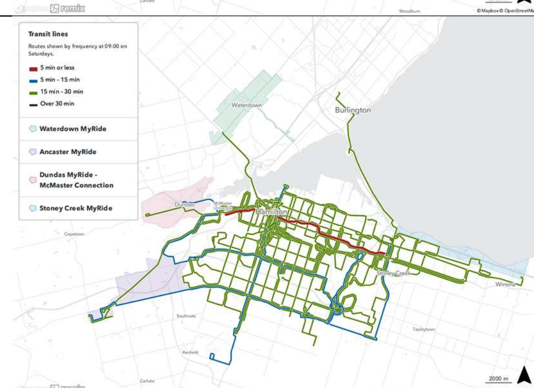
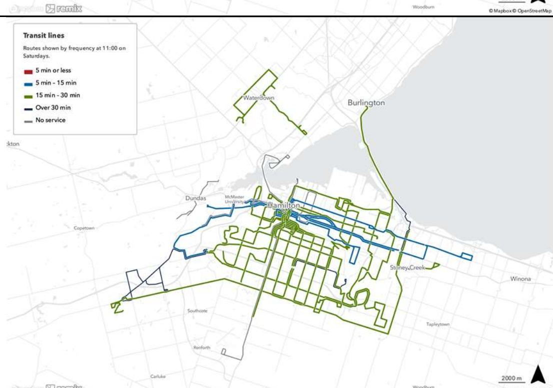
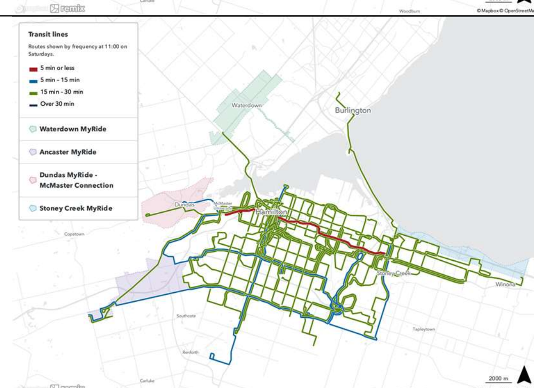
05:00		
07:00		
09:00		
11:00		

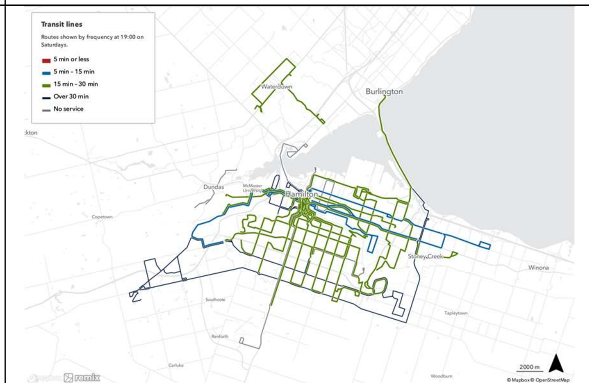
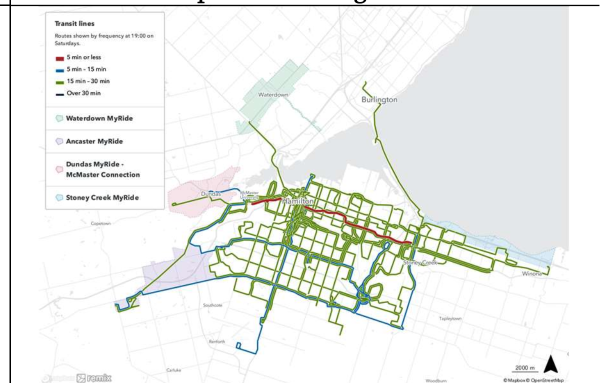
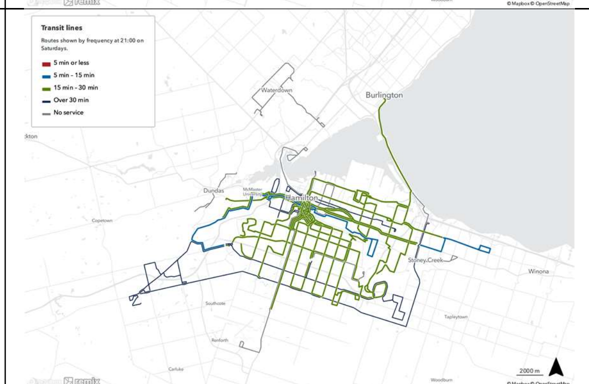
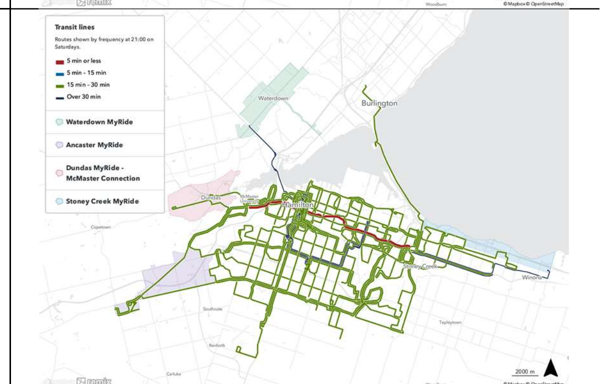
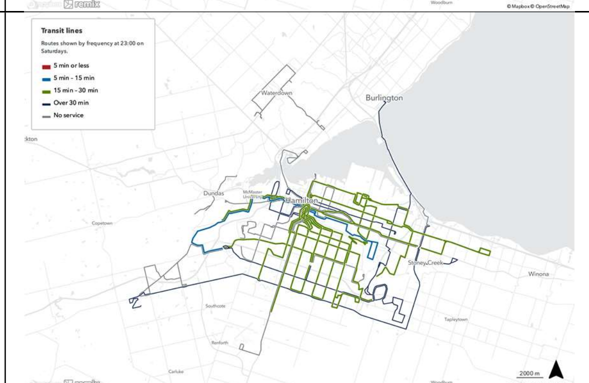
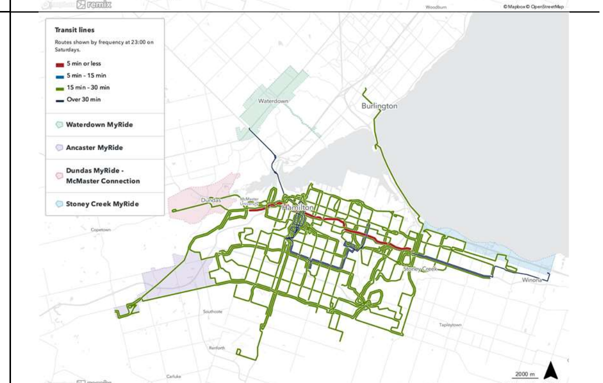
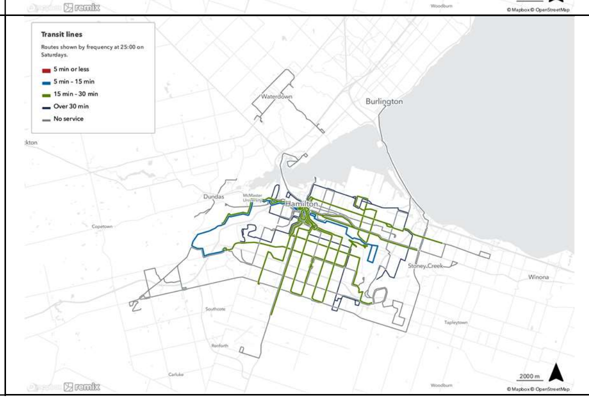
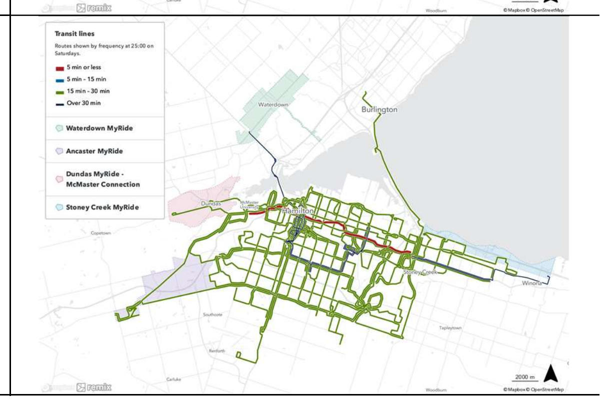
Time	Current HSR Network	Proposed Reconfiguration
19:00		
21:00		
23:00		
25:00		

Table 5-3: Comparison of current and proposed HSR networks (frequency - Sundays)

<table>
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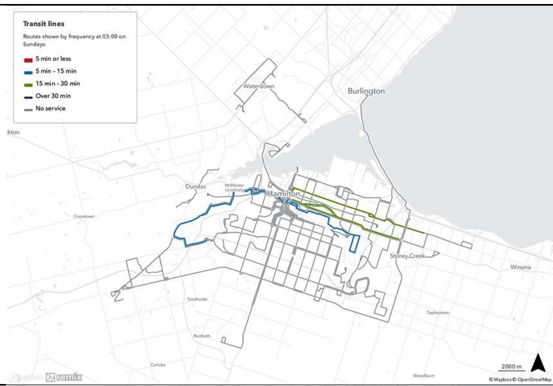
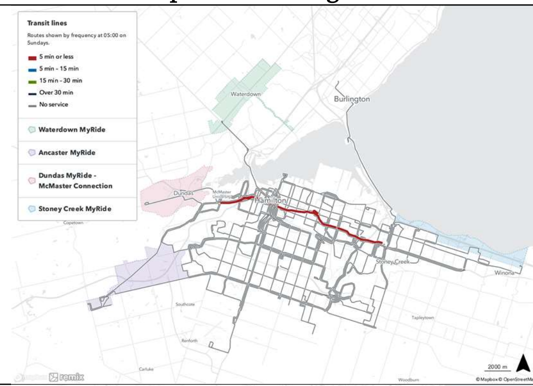
<tr><td>05:00</td><td>
</td><td>
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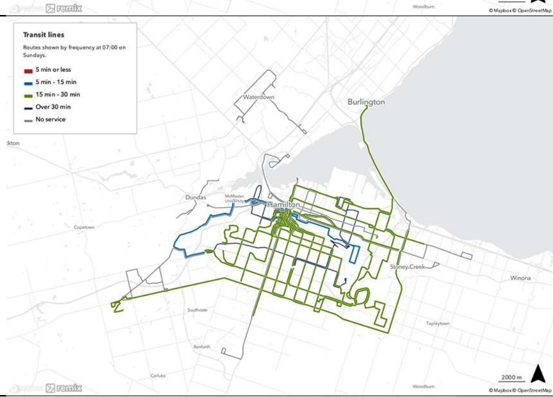
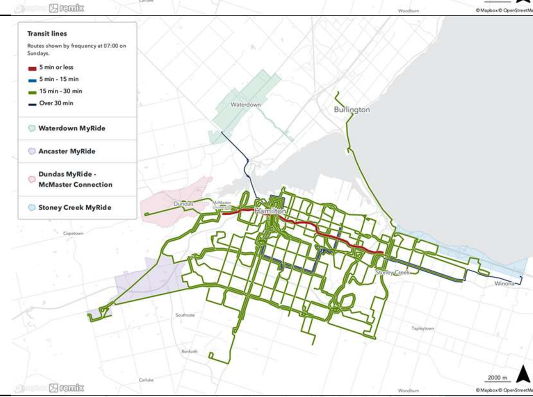
<tr><td>07:00</td><td>
</td><td>
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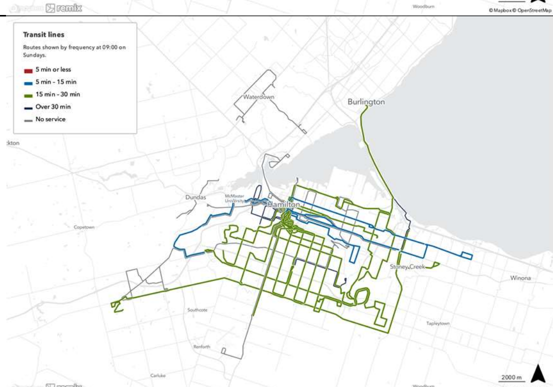
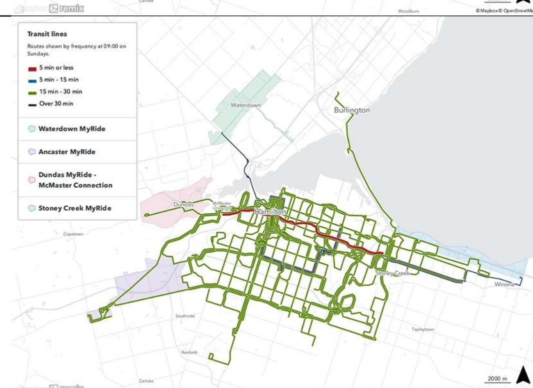
<tr><td>09:00</td><td>
</td><td>
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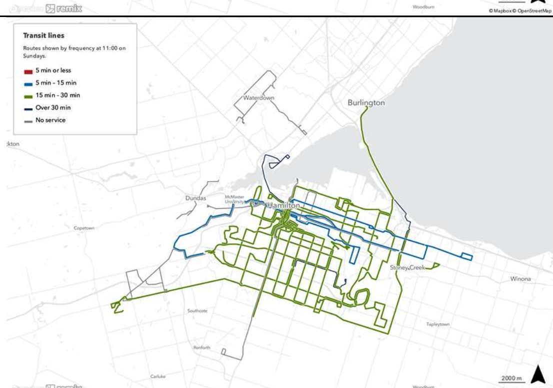
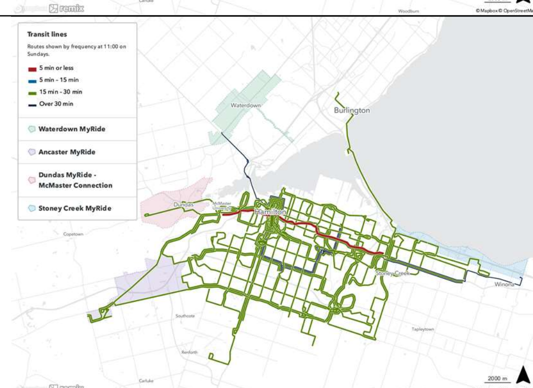
<tr><td>11:00</td><td>
</td><td>
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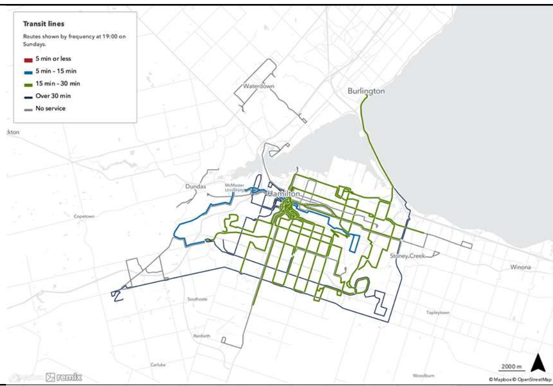
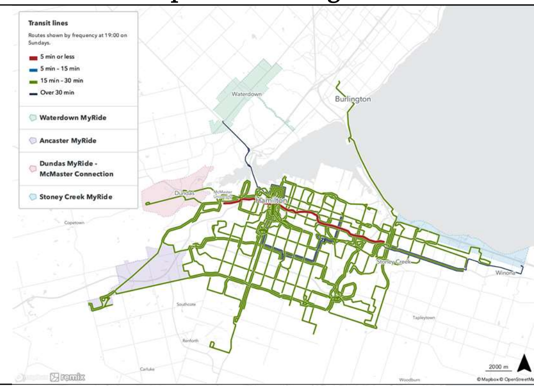
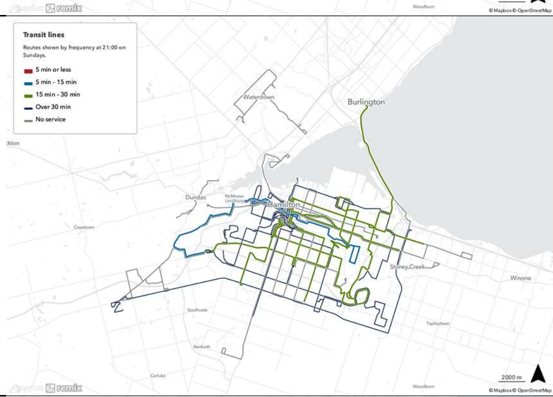
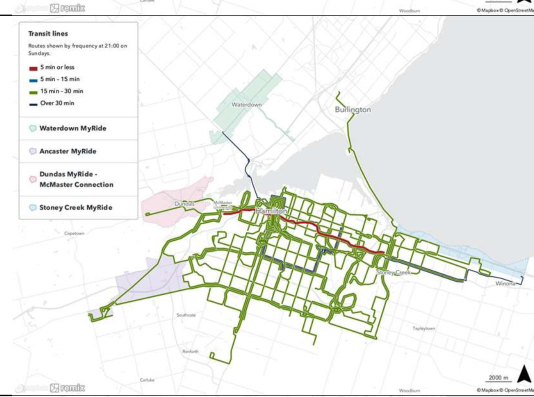
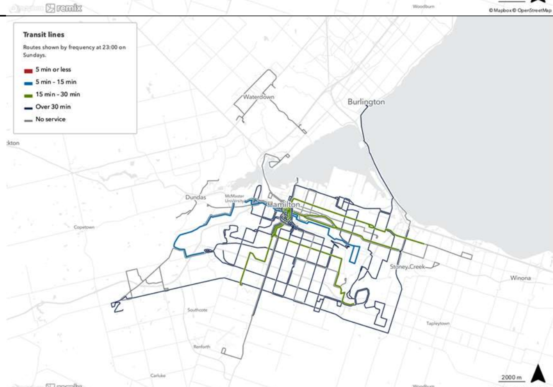
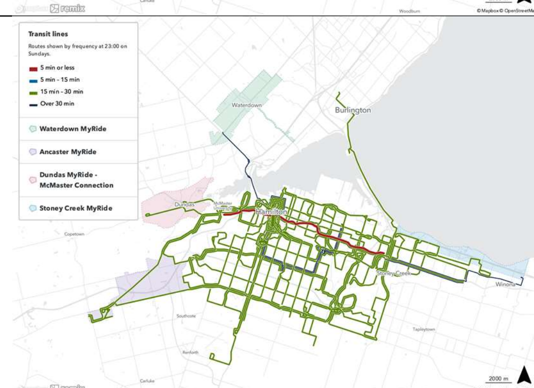
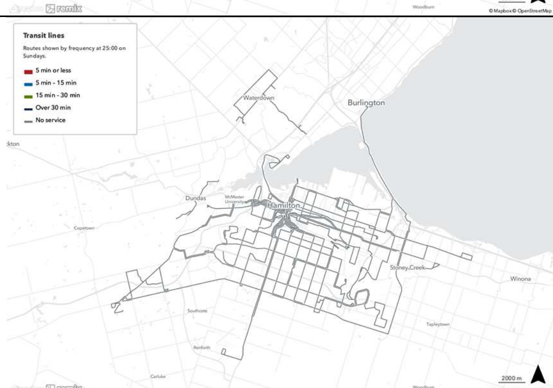
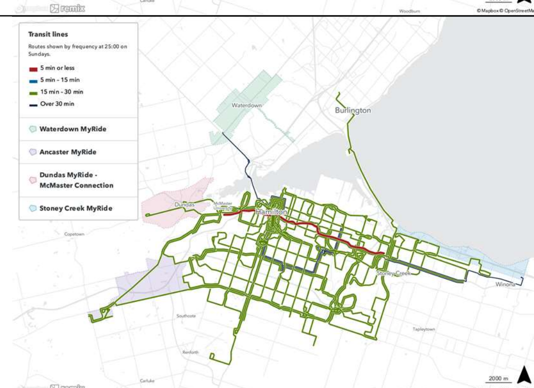
Time	Current HSR Network	Proposed Reconfiguration
19:00		
21:00		
23:00		
25:00		

CHAPTER 6

CONCLUSIONS

6. Conclusions

This report is aimed at suggesting a multi-criteria reconfiguration of HSR transit service based on the evidence of our data collection and modelling efforts. The report, therefore, links previous reports to the proposed HSR network reconfiguration. The concluding remarks are arranged following the sequence of the report and presented in a bullet point format.

It should be noted though, that the cost values reported herein are extracted from Remix software. The software provides a relatively accurate approximation of the cost. However, to determine precise costs that are inclusive of all the variables specific to HSR staff and fleet resources, additional and resource demanding run-cutting and scheduling analysis is required. Therefore, additional analysis is required to model, fine-tune, optimize and cost the implementation of the proposed network reconfiguration at the micro-level using the HSR's comprehensive transit planning resources and network modelling software (Trapeze).

- The wealth and depth of data collected from several sources presented a unique opportunity to reconfigure the HSR network and operation based on multi-criteria. The developed models echoed almost similar indications for service reconfiguration and ultimately increasing HSR ridership.
- The total-trip journey philosophy was implemented, and Hamiltonians' travel needs were classified at Micro, Meso, and Macro scales. This classification is used to develop HSR route hierarchy yielding Higher-order, Express, Regional, Collectors, and Local route-types.
- Furthermore, the reconfiguration guidelines were developed based on integrating the findings of all previous reports. The reconfiguration is guided by eight guidelines to facilitate seamless transit travel for all Hamiltonians. These include: 1) Hub-to-Hub No-Transfer Service, 2) Hub-to-Origin/Designation One-Transfer Service, 3) Higher-Order Fast-Frequent Transit Service, 4) Regional-Connectivity, 5) Resilient and Robust Network, 6) Last-Mile Accessibility All Week, 7) Enhanced & Reliable Level of Service, and 8) Demand-based Stop/Infrastructure planning.
- Accordingly, eight HSR hubs are identified in Hamilton, along with four (Hamilton Go Centre, West Harbour GO, McMaster Go Transit Terminal, Centennial Go Transit Rail Terminal) access stops to regional connectivity.
- A decision was made to introduce two Bus Rapid Transit (BRT) routes that would partially operate on dedicated corridors (initially proposed for Hamilton-LRT Line B). This decision was based on the high transit demand across this corridor and the uncertainty associated with the provision of Hamilton-LRT. That said, should Hamilton LRT project moves forward, additional analysis must be completed to ensure the integration of the proposed network reconfiguration with the Hamilton LRT project.
- The integration of implementation of the reconfiguration guidelines for the HSR network yielded a proposed network of 39 routes (2 BRT, 5 Express, 3 Regional, 16 Collectors, and 13 Local routes).
- The proposed network contributes to a 7% increase in the population served by transit within a 400-meter buffer. Furthermore, there is an approximately 49.71% increase in the number of trips on Sundays/Holidays and a 45.75% increase on Saturdays. On Weekdays, the number of trips increased by 28.91%.

- Further, the proposed reconfiguration supports access to economic opportunity with a 3.33% increase for occupied dwellings, and 7.16% increase for the total number of employees within the 400-buffer threshold. Nonetheless, the percentage of the low-income population within 400 meters buffer decreased by 0.40%.
- That said, these values reflect only the network coverage regardless of service operating parameters. In this respect, accessibility to the service (with respect to the frequency of all routes) has enhanced substantially. The reachability (distance covered over time) from/to the proposed eight hubs significantly increases throughout Weekdays, Saturdays, and Sundays. This indicates that the proposed network reconfiguration provides superior travel time.
- Adding to that, the hierarchical route structure coupled with hub-to-bub connectivity contribute to a more robust and resilient network, which could withstand disruptive events.

Overall, this report provides a ready-to-implement HSR network reconfiguration that is based on the travel needs of Hamiltonians, which is expected to increase transit ridership substantially.

CHAPTER 8

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