

Does initial background matter in evaluating Light Rail Transit feasibility in North America mid-size cities?

by

Shangwei Yu

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Author's Declaration

I hereby declare that I am the sole author of this thesis. This is a true copy of the thesis, including any required final revisions, as accepted by my examiners.

I understand that my thesis may be made electronically available to the public.

Abstract

A transit system may be one of the most profoundly influential investments in modern cities.

In declining cities, local governments consider new transit investment as medicine to cure their problems. However, in emerging cities, transit investment is considered a booster. Considering the complexity and uncertainty, a feasibility study for Light Rail Transit systems is very challenging. Existing studies usually follow a similar assessment method. With different starting backgrounds, the transit systems could have significantly different performances. Typical assessment methods fail in every project. Many LRT projects failed to meet their design goals.

Existing research and planning processes usually do not take a city's initial condition as a meaningful factor in the assessment process. This research aims at exploring if the initial condition is an influential factor in the success of transit investment and the performance of the transit project. The City of Buffalo and Region of Waterloo are selected as two case studies to achieve this goal. They have dramatically different initial conditions and LRT performance. A series of demographic and social-economic census data are collected to complete a multi-variable analysis. This research shows that the initial condition has a critical impact on the transit investment, and the declining city cannot automatically benefit from the transit investment.

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Dedication

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Chapter 1 Introduction

1.1 Research Background

City transportation networks have dramatically changed during the industrial era, with even more rapid evolution taking place in the last hundred years. After the introduction of mechanically powered transportation systems, public transit was widely used in urban settings to meet people's demands (Moller, 2014). In the late 19th century, the bus network and streetcar system offered people (relatively) fast, reliable, and comfortable trips. However, since the 1920s, the public has shown great interest and acceptance of private vehicles. In the decades after World War II, highway networks became North America's most significant transportation projects, accelerating the widespread adoption of the automobile as a primary transportation mode.

Beginning in the 1970s, the trend of population dispersion from city centers to suburban regions was followed by a similar outward movement of employment. Many North American cities began to lose not only population in their urban cores, but also employment. These concurrent phenomena led city planners and other professionals to seek methods to revitalize downtowns – motivating public and private investment into existing urban cores.

One effort to increase transportation capacity and to make urban centers more attractive included investment in higher order transit systems. Light Rail Transit (LRT) experienced a renaissance in North America that began in the late 1970s and early 1980s (Sinclair, 2019), with systems being built in Edmonton, Calgary, San Diego, Pittsburgh and Buffalo (Bliss, 2020). In subsequent decades, from 1990 to the present, more than 20 other North American cities carried out light rail transit or streetcar projects.

Billions of dollars in investments from all levels of government have been made to support these projects (Higgins & Ferguson, 2012). LRT projects are usually constructed on an existing road network and can provide a higher capacity and more reliable service than the bus system (Reales, 2014). Because of their lower (than heavy rail or metro systems') costs, and scalable capacity, LRT systems have been attractive for both large and mid-size cities. The term "mid-size cities" typically refers to urban areas that are smaller in both geographical and demographic scale than megacities. It is worth noting that the specific criteria used to define mid-size cities may vary depending on the

country in question. In the case of North America, mid-size cities are generally classified as metropolitan areas with populations ranging from 50,000 to 500,000 individuals (Wagner & Growe, 2021).

As is the norm for all major infrastructure investments, local governments considering an LRT system typically perform a comprehensive and detailed feasibility study and environmental impact assessment which identifies the potential benefits and impacts of the proposed system. Critical components that are regularly included in assessments of benefits include decreased congestion in urban areas, increasing the likelihood of higher density in areas served by the system and, as a result, lower cost transportation that generates fewer negative environmental impacts.

Ideally, LRT investments are projected to improve accessibility and reliability of public transport, making the service more attractive. As a result, the expectation typically follows that the LRT project will change people's travel behavior, increasing the accessibility and ease of travel to the downtown area. With lower transportation costs, the reasoning continues, there will be a motivation for residents and firms to locate in the city center, resulting in new development and economic growth. The underpinnings of this process are commonly referred to as Transit Oriented Development (TOD) (Curtis, Renne, & Bertolini, 2009).

The costs of the proposed projects typically include the monetary costs to build, operate and maintain the system, as well as any disruptions that result from the construction process. There is an obvious interdependency between the estimates of benefits and costs. If a proposed system *is successful* in influencing land use and travelers' behaviors, then the revenues generated from the system from riders' fares, increased property taxes, and overall economic growth will help recover the initial investment and offset the operational subsidies that transit systems in North America nearly always require.

If, however, a system is constructed and *fails to influence* land use or attract ridership, then the financial and societal benefits are much lower. As a result, the value of the public investment is likely much lower, and the opportunity costs associated with this investment – allocating massive sums to a transportation project that might otherwise be dedicated to a public project with a better return on investment – become enormous.

Given this relationship, the ability of transit investments, particularly LRT investments to achieve positive outcomes has received substantive attention in the literature (Love, Ahiaga-Dagbui, Welde, & Odeck , 2017). The evidence suggests that the vision of transit investments achieving substantive changes in transportation behavior, land use, and economic development has been realized to varying degrees in cities around North America (Higgins, Ferguson, & Kanaroglou, 2014). In some cities, LRTs have been impactful in transforming urban environments, supporting in part the creation of high-density vibrancy that may not have been realized absent the investment. However, in other settings, the LRT suffered from low ridership, cost overruns and poor reliability problems (Baker & Lee, 2017). From a city level, there were no apparent improvements in new development and employment opportunities after the completion of the light rail network. This variance in the success and failures of previous projects make evident that existing assessment measures are not always effective in predicting the success of the LRT projects.

Naturally, the likelihood of an LRT investment achieving its goals depends on a wide range of variables, many of which are beyond the control of governments developing the system. Transit ridership is known to be positively correlated to the price of private automobile travel, including the purchase price of cars and fuel costs. As local, national, and global economies evolve, local areas may become more or less attractive to firms making location decisions. Thus, it is to be expected that not all initial assessments of new transit investments or expansions to existing systems will be accurate in their forecasts.

There are, however, data available to those conducting systems assessments that may be valuable but have not regularly been part of the forecasting process. During the feasibility study and Environmental Impact Assessment process, initial urban conditions – the trajectories of population, employment, densities, and demographics – are essential terms that need to be studied. To demonstrate this point, consider a proposal for a light rail system in a city where population is growing; employment is also increasing and more disaggregate, the growth in employment is taking place in sectors known to be more likely to be positively correlated with public transportation use. Because this hypothetical city is home to a very large university, the population is comprised of a disproportionate number of 18- to 30-year-olds, again who have been shown in other research to have greater likelihoods of riding transit. Now imagine that this city is located within a larger government structure that has been implementing policies to increase land use densities, protect environmentally sensitive areas, and reduce its overall carbon production.

Suppose now that there exists a second, contrasting city that is also contemplating light rail investments, but for which the population and the number of jobs is declining, there is an outward movement of both residents and employers, and in which the urban core has very low occupancy rates, coupled with a perception of high crime rates.

Finally, let's assume that at the time of planning the LRT, the static input data for the two cities are the same – same population, employment, densities; let's also assume that the physical infrastructure and natural conditions are the same. Despite these similarities, it would be unreasonable to think that the LRT systems being contemplated for these two cities have equal likelihood of success.

What this overly simple example illustrates is that understanding the initial urban conditions is essential for effective urban planning, as it provides a baseline for assessing the potential impacts of proposed interventions and for developing strategies that build on existing strengths and address existing challenges.

1.2 Significance and Purpose of Study

Compared with large cities, transit projects are sometimes subject to more risk in mid-size cities for many reasons. First, based on existing research, mid-sized cities in North America typically have a lower population density and a more expansive city structure. Mid-sized cities are often “auto-dependent” – with large mode shares by private auto and, in some cases, with urban street designs and built environments that limit the capacity to walk (or cycle), further diminishing the likelihood of travel by transit (Cervero & Radisch, Travel choices in pedestrian versus automobile oriented neighborhoods., 1996; Maria , 1997; Boarnet & Sarmiento, 1998). Similarly, major investments in rail transportation are less common in mid-sized cities, because the magnitude of the outlay – often in the range of \$40-\$100M per kilometer – is often perceived as out of scale with the city size (Casello , Lewis, Yeung , & Santiago-Rodríguez, 2014). Considering the cost and scale of transit projects, mid-size cities’ governments must make substantial, and continued financial investments to build and operate these projects for decades. Investment in rail transit projects can consume a considerable proportion of their budget and economic availability, creating large opportunity costs in choosing transit projects. If the transit project fails or does not meet the expectations, it may take decades for the city to recover from this bad investment.

On the other hand, transit systems (existing and new investments) can have a large influence on mid-size cities. In mid-size cities, transit projects are more likely to lead to new developments which have transformative impact on urban structure especially in the downtown area (Higgins, Ferguson, & Kanaroglou, 2014). Moreover, from people’s travel mode perspective, people in mid-sized cities have limited chances to get access to rapid transit services. Unlike many large cities which have mature subway networks, the transit networks in mid-sized cities typically rely almost exclusively on buses operating in mixed traffic. As a result, the bus system is both less reliable and less attractive to people. Investing rapid transit system in mid-size city can better meet people’s demand.

The planning process that precedes any substantive infrastructure investment intends to establish goals for the project, and to assess the likelihood of achieving those goals. This approach has been followed for the recent investments in Region of Waterloo, Ottawa, Phoenix and many other North

America cities. Before each project was designed and constructed, there were a series of detailed feasibility studies which included a variety of factors. In these feasibility studies, planners and researchers reviewed the socio-economic situation and projected cities' future development. These studies usually followed a similar process and set up similar objectives for their rapid transit projects. These goals regularly include limiting the expansion of the city, improving air quality, changing people's behavior, and revitalizing downtown areas.

What is not regularly identified in these studies is that cities proposed their investment based on different existing conditions – various trajectories which undoubtedly influenced the likelihood of achieving certain goals. In some cities, local governments proposed a rapid transit project with the goals of addressing economic development, particularly slowing, or reversing urban decline, especially for the downtown area. For some other cities, local governments may introduce rapid transit services to better meet their demand and accelerate their development. Naturally, the likelihood of success for these outcomes depends significantly on whether the cities are naturally growing – increasing their population and employment – or experiencing decline.

In the literature assessing (in retrospect) the performance of LRT systems relative to their articulated goals, the results are quite mixed, with many systems failings to achieve their stated objectives. What has been missing from both the planning efforts and the post-implementation evaluation is a careful consideration of the pre-construction trajectories. Few experts and researchers recognize that urban growth trends could impact transit projects' performance and the attainment of TOD (Transit Oriented Development).

This study will focus on how different background situations can affect the performance of rapid transit system relative to expectations and forecasts. In this research, the concept of urban growth trajectory is used to represent a city's initial background by incorporating its developmental trends. It provides a comprehensive overview, encompassing various socio-economic factors to describe the city in detail. The outcome of this research adds more information that ultimately may explain

whether rapid transit projects are more likely to meet their objectives and lead to improved assessments of future projects.

1.3 Research Questions

This research focuses on the relationship between initial conditions and the propensity for successful Light Rail projects. As the initial conditions are elements that are not routinely considered in feasibility studies, the research question in the thesis is:

- Does initial background matter in evaluating LRT feasibility in mid-size cities?

A list of sub-questions needs to be answered to answer this primary research question. These sub-questions are small objectives in this research and can help to answer the primary research question.

- What are the commonly articulated, expected impacts of LRT projects, and how are the metrics of these impacts developed?
- What are the assessment methods used by existing feasibility studies for LRT projects?
- What factors could be considered to describe the initial conditions for a city and how should these be included in the assessment process?

The sub-questions in this research reiterate the importance of recognizing the LRT project's direct and indirect impacts. Moreover, this research also reviews the existing assessment methods and identifies the limitations. Finally, this research offers a multi-variable method to measure and describe the initial development trajectory of a city. These steps are taken to finish the primary objective, which is exploring the relationship between the initial condition and LRT's performance. The outcome of this research suggests that including initial condition analysis in feasibility studies may add value. More importantly, this research aims at helping to improve the accuracy of the feasibility study, which can improve the efficiency of new proposed LRT projects and possibly reduce risk.

1.4 Thesis Outline

The outline of this thesis is organized into the following chapters and sections. Chapter 2 presents previous literature to introduce and discuss LRT in mid-size cities and existing Environmental Assessment methods, providing theoretical information to highlight the significance of this research and gaps in existing studies. Chapter 3 details the methodology, explaining the research framework, generation of a multi-criteria evaluation system, and data collection and analysis process. Chapter 4 presents the results, summarizing the findings from the City of Buffalo and the Region of Waterloo, and compares whether transit projects like light rail transit could have different impacts in cities with different urban growth trajectories. Chapter 5 reviews the research method, addresses limitations, summarizes the findings and conclusions, and offers recommendations for future planning works and analyses to incorporate urban growth trajectory as a significant element in transit project planning.

Chapter 2 Literature Review

2.1 Chapter Outline

The previous chapter has outlined the research questions, the purpose and significance of the research question and the format of the thesis.

The objectives of the chapters are to:

The previous chapter has outlined the research questions, the purpose and significance of the research question and the format of the thesis. The objectives of this chapters are to:

- Identify urban issues related to Auto-Oriented cities and introduce the importance of the Transit-Oriented Development
- Introduce the history and features of the Light Rail Transit Network
- Define what Mid-Size Cities are and some of their challenges and opportunities
- Explain why Mid-size cities are suitable for LRT projects
- Introduce the application and importance of Feasibility Studies and EIAs
- Introduce and explain how feasibility studies for transit projects are designed and what factors are included
- Critique the success of existing Light Rail Transit projects and identify the influential missing factors.

2.2 From Auto-Oriented to Transit Oriented

Decades after World War II, massive highway networks, the trend of suburbanization, and affordable private vehicles all contributed to the popularity of automobiles (Mcleod, 2011). The popularity of automobiles changed people's lifestyles and led to auto-dependence in North America. Auto-dependency – the exclusive reliance on private automobiles, coupled with planning and design that effectively precludes the use of other modes – is prevalent throughout the post-war history of North American cities, to the extent that it has become an icon and part of the culture in North

America (Janushewski, 2014, p. 13) . Initially, planners and cities welcomed the auto-oriented concepts by proposing auto-oriented city layouts (Foster, 1981, p. 81). However, the auto-oriented development was soon proven to be unsustainable. Jane Jacob (1961) was among the first and most vocal critics of what she described as poor urban planning. She and others acknowledged that auto-oriented city design is also related to many urban issues, including, traffic congestion, high energy consumption, uncontrollable sprawl expansion, lack of mass transit, and declining urban centers (Janushewski, 2014, p. 35).

Even though there are many problems and disadvantages to an auto-oriented lifestyle, it is difficult to change people's behaviour; the most common contemporary efforts to achieve different transportation behavior is through city design and the provision of suitable alternative transportation options (Gössling, 2020, p. 446). Common examples include car restrictions, motivating shared modes, and the creation of bicycle networks. Through previous experiences, they are not the ideal solution when considering the performance and cost (Gössling, 2020, p. 447).

Many have argued that public transit, with its very high capacities, low space utilization, and lower energy per unit of travel, has great potential to handle the transportation crises existing in urban centers (Vuchic V. R., *Transportation for Livable Cities*, 1999, p. 37). Public transit systems are open and available for all populations in cities. In addition, public transit is more environmentally friendly and has fewer requirements. Therefore, public transit has different types of modes which could better serve other demands and play a variety of roles in the metropolitan area (Ušpalytė-Vitkūnienė & Burinskienė, 2008; Vuchic V. R., *Transportation for Livable Cities*, 1999).

By moving from auto-oriented to transit-oriented, cities focus on expanding and improving their transit network. Coupled with the investment in transportation systems, planners also proposed relocating the development to station areas, developing what is now referred to as Transit-Oriented Development (TOD) concept. TOD includes high-density, mixed-use development located close to public transit infrastructure (Thomas & Bertolini, *Transit-Oriented Development: Learning from*

international case studies, 2020, p. 2). On the one hand, TOD aims to encourage high-level density development around major transit stations which could maximize the effectiveness of the public transit system (Thomas & Bertolini, Defining critical success factors in TOD implementation using rough set analysis, 2017, p. 2). On the other hand, TOD aims to promote walking, cycling, and using public transit to improve the sustainability of urban transportation (Institute for Transportation & Development Policy, 2015). For North American Cities, Transit-Oriented Development was widely accepted because it appears to be a promising solution to urban issues (Schuetz, Giuliano, & Shin, 2017, p. 1676).

2.3 Why Light Rail Transit in Mid-Size Cities

2.3.1 Introduction to Light Rail Transit

Urban rail systems were initially created in the late 1800s and early 1900s. The systems began to erode in popularity after the first World War, with that trajectory increasing after World War II. As discussed earlier, the introduction of the automobile in the post war period led to a substantial decline in North American transit ridership and, in many cities, the replacement of original surface rail systems with buses. Since the late 1960s and 1990s, however, awareness grew regarding the environmental and social shortcomings of auto-dependency (Alpkokin, Topuz Kiremitci, Black , & Cetinavci, 2016). In response, many cities began to evaluate the possibility of improving their transit systems, without the very large investments necessary to build urban subways (Farran, 2013; Victoria Transport Policy Institute, 2015).

Given these complementary forces, Light Rail Transit (LRT) began to get renewed attention as a possible solution to urban development challenges. The essential difference between modern LRT and the streetcar system is the right of way – the degree of separation from other modes. Streetcar systems generally operate in mixed traffic, under conditions described as Right of Way C (ROW C). LRT systems typically operate at grade, but with longitudinal separation (Right of Way B, ROW B) between the LRT and other modes; LRT systems have the flexibility to operate in mixed traffic or in fully grade-separated alignments (Right of Way A, ROW A) as well (Vuchic V. R., Light Rial Transit System- A Definition and Evaluation, 1972). Comparing LRT systems to subways, which are

operated exclusively on ROW A requiring massive investment in tunnels or elevated structures, LRT systems require substantively lower investment costs because of their capacity to operate on existing roads (Liu, 2013).

Light Rail Vehicles (LRVs) are defined as electrically powered, single vehicles (with or without articulation) that may be coupled to create a train. LRVs have positive physical attributes for operations in metropolitan area (US Department of Transportation, 1996), including the ability to operate with small turning radii, and at disparate speeds, depending on the alignment. Light Rail Vehicles have evolved from streetcars, which were typically 4-axle electronic powered vehicles, to up to 8-axle, and vehicles could be articulated. As the number of axles increases on a vehicle, the distance between those axles, is reduced, thereby allowing tight turning radii, consistent with urban spaces. Existing LRT projects show that LRT systems have operating speeds ranging from 15-31 mph (25-50 kilometres per hour). Depending on frequencies and train consists, line capacity for LRT systems can vary widely, with maximum values observed at 15000 - 18,000 passengers per hour (Mansel, Menaker, & Hartnett, 1998). Given the flexibility in attributes, cities considering LRT investments can carry out their standard for LRV and find the best product that best meets its demands.

2.3.2 LRT for Mid-Size Cities

In North America, almost one-quarter of the population lives in urban areas that can be described as a Mid-size city, with populations between 50,000 and 500,000. Unlike large cities (e.g., Toronto, Calgary) and megacities (New York, Los Angeles, Mexico City) that attract people's attention, there has been a limited number of research studies focused on mid-size cities (Wagner & Growe, 2021). Emerging planning concepts and strategies like intensification, re-urbanization, new urbanism, and smart growth all bring new opportunities and challenges for mid-size cities (Bunting, Fillion, Hoernig, Seasons, & Lederer, 2007). Unlike the megacities, mid-size cities have their own urban issues and challenges. For example, research shows that mid-size cities in North America are more vulnerable to the low-density issues due to counter-urbanization (Bunting, Fillion, Hoernig, Seasons, & Lederer, 2007, p. 35; Halfacree, 2009).

Many mid-size cities (Kitchener-Waterloo-Cambridge, Regina, Saskatoon, Victoria, and Kelowna) have recognized the low-density issue and showed their willingness to control the urban sprawl and promote high-density development in those cities (Graham, Han, & Tsenkova, 2019, p. 516). Investing in transit networks has in some instances been a good option to attract business and people back to a city's core by providing high-capacity reliable transit service. Existing studies have identified that light rail is the most effective mode to stop population loss (Christopher, Seymour, & Schleith, 2018). Under these circumstances, LRT is more than a transit or transportation project but also offers the possibility to influence other public goals within a city. Local governments usually include LRT and following TODs into their development strategies to achieve large planning objectives.

Among different transit options, Light Rail Transit can best meet the transit demand of mid-size cities. Evidence on global cities with LRT systems demonstrates their applications in cities of this size. About 80% of LRT projects are in larger cities – those with populations greater than 200,000 (Light Rail Transit Associate, 2019). Knowles and Ferbrache (2016) held the view that cities with a population of more than 300,000 are appropriately sized to gain benefits from an LRT system. The introduction of LRT into Mid-Size Cities has been shown to be particularly impactful, given the perceived higher-than-normal investment that such systems require. In some cases, the public has perceived these investments as resulting in very high quality services that not only meet the demand in mid-size cities, but also attract new riders (Flannery, et al., 2015).

Financially, LRT also offers benefits in mid-size cities. Unlike the mega cities, mid-size cities have limited financial resources and great challenges to meet their financial obligations (Tassonyi, 2017). Light rail projects have great advantages compared to the heavy rail system, with average construction costs for LRT projects equaling about 25% of heavy rail's cost (Cervero & Guerra, Urban Densities and Transit: A Multi-dimensional Perspective, 2011). Lower construction costs make LRT project more achievable in mid-size cities.

2.4 Feasibility Studies and EIAs

2.4.1 Feasibility Studies, Environmental Assessment & Environmental Impact Statement

A feasibility study is a detailed analysis that considers all essential aspects of a proposed project to determine the likelihood of success (Shen, Tam , Tam, & Ji, 2010, p. 255) as well as additional elements that are necessary to minimize negative impacts during and after construction. A Feasibility study is a method that is widely used in medical, engineering, business, and investment fields. For all projects, a feasibility study is the first and most crucial step before design and application (Shen, Tam , Tam, & Ji, 2010, p. 255). A feasibility study can provide a clear idea of a proposed project and validate the reason why this project needs to be built (Mukherjee & Roy, 2017). In addition, a feasibility study also outlines a series of objectives for the project and these objectives are essential criteria to evaluate the success in the future (Mukherjee & Roy, 2017).

A proper feasibility study is essential to properly assess the likelihood of achieving a project goals and the additional steps necessary to do so in ways that meet broader objectives (Dvir, Lipovetsky, Shenhar, & Tishler, 1998). The feasibility study needs to review the project from both the proponents' perspective, which for transportation projects is often a level of government, and society's perspectives to ensure the project is feasible (Mukherjee & Roy, 2017). Typically, feasibility studies can be categorized into five different aspects:

Technical feasibility – meaning is the project physically able to be designed and built with current engineering and construction techniques.

Economic feasibility – meaning is the project able to be planned, designed, constructed, operated and maintained within the budget constraints, recognizing disparate time scales of analysis.

Legal feasibility – evaluating whether the project's planning, design, construction, operations and maintenance can be legally accomplished. As an example, environmental

regulations may preclude access to lands that are necessary for a project which would make the project infeasible.

Operational feasibility – evaluating a project’s post-construction operations and determining if those activities will meet the project’s goals; and

Scheduling feasibility – determining if the project timelines from planning to operations are consistent with the project’s goals.

Naturally, there is interdependence between these aspects of feasibility. There may be methods to address shortcomings in technical or scheduling flexibility by increasing spending; but that spending may render the project infeasible. The exact format of a feasibility study will depend on the type of organization leading the initiative. It is also common that within a feasibility analysis, some evaluators may assign different weights to the relative components, based on the assessors’ area of concern (Shen, Tam , Tam, & Ji, 2010, p. 255).

Environmental Assessment (EA) and Environmental Impact Assessment (EIA) are studies required by the environmental protection regulations in both Canada and United States. Even though the names are slightly different in two countries, they have a similar objective which focuses on the decision-making process regarding environmental impacts (Caro-Gonzalez, Toro, & Zamorano, 2021). Any projects that could have a significant environmental impact are subject to the Environmental Assessment; the level (Provincial, Federal) at which the environmental assessment takes place depends, in part, on the nature of the project and its funding sources. The purpose of EIA is to incorporate a variety of technical tools to identify, predict, evaluate, and address the environmental impacts that should be prevented and mitigated (Morrison-Saunders, 2018). A typical Environmental Assessment process includes scoping, screening, examination of impact, impact analysis, impact management, preparing Environmental Impact Statement (EIS), reviewing EIS,

decision making, and future monitoring (Steinemann, 2001).

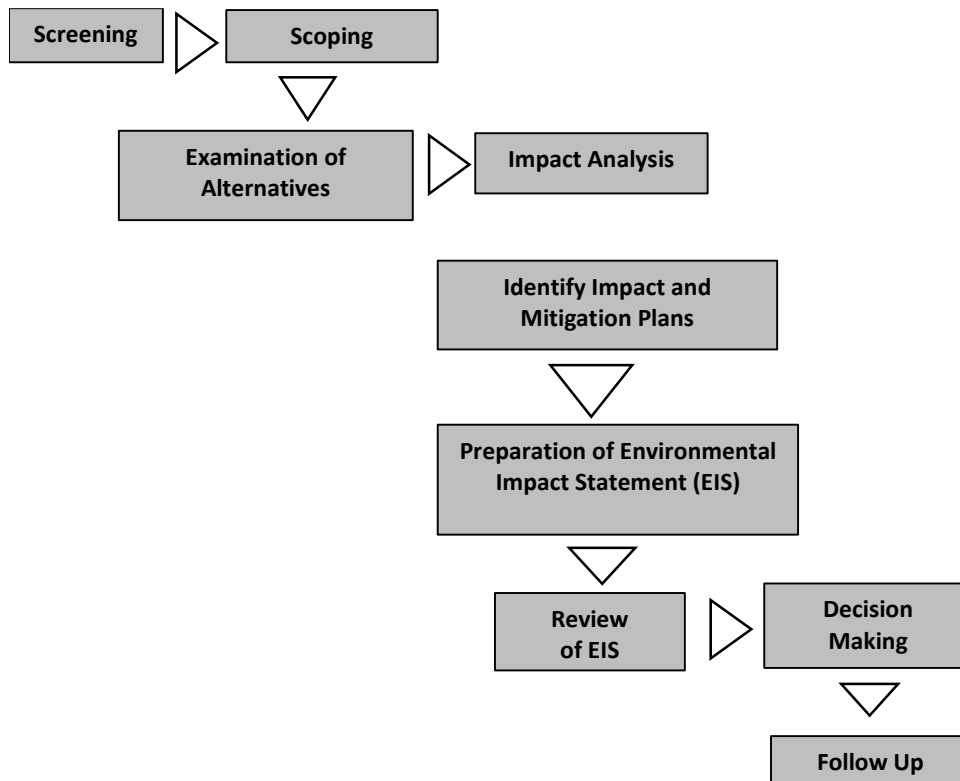


Figure 2-1 EIA Process

Screening and Scoping make up the design process of the environmental assessment studies. For screening, the project is reviewed and determined whether an EA process is required. If an EA is involved, the Scoping process determines which impacts and issues should be considered (Glasson, Therivel, & Chadwick, 2019).

Impact Analysis and Impact management section are the most essential parts of the EA. During the study, researchers used a variety of methods to evaluate the project's potential impacts.

Alternative studies typically include several feasible approaches to achieve the overall project objectives. Often, alternative proposals will differ by project location, scales, processes, layouts, operating conditions (Glasson, Therivel, & Chadwick, 2019). In the EA process, "No-Action" is included as an important alternative based on the legal requirement

(Steinemann, 2001). The goal of including the No-Action alternative is to ensure that any project investment will result in an improved outcome, relative to status quo.

The description of the environmental baseline includes setting up existing and future environments in the absence of the project. Environmental baselines are critical methods to evaluate the project's impact (Glasson, Therivel, & Chadwick, 2019).

Identification and Prediction of Impact brings outcome of previous steps together to identify and estimate all dimensions of environmental impact (beneficial and adverse). These impacts are compared with the situation without the project.

Mitigation Plans aim to introduce measures to avoid, reduce and compensate any significant adverse impact (Glasson, Therivel, & Chadwick, 2019).

Preparing Environmental Impact Statement seeks to document and provide a summary of the processes, assumptions and evaluations made assessing the project and to communicate those elements for review by interested and affected parties.

Decision-Making Process involves related government department and other stakeholders to review EIS and make the final decision to approve the project.

Following Up involves auditing work to compare actual project impact and predicted impact. It can also lead to further studies to explore the accuracy of prediction and the effectiveness of mitigation.

Environmental assessment studies usually finish prior to major decision being taken and commitment being made (Noble, 2021). Performing an environmental assessment study has a variety of benefits including avoiding or mitigating significant adverse environmental impacts, promoting public participation and Indigenous consultations, identifying unforeseen and unwanted impacts, increasing public acceptability of a project and a reducing the probability of project delay (Noble, 2021). Therefore, performing an Environmental Impact Assessment is not only a legal requirement but also an essential process to ensure the success of the project.

2.4.2 EIA for LRT projects

Transit projects like Light Rail Transit are intricately connected with social, economic, political, environmental, and other factors. Feasibility studies are mandated and result in comprehensive reviews of the engineering, planning and environmental factors along the corridor (Matsoukis, 2003, p. 26). The complexity of the LRT project makes feasibility studies greatly needed.

Light Rail Transit projects are subject to the environmental assessments. While regulations regularly evolve, in most jurisdictions LRT projects go through the EA process. The legal requirement holds true in both Canada typically at the Provincial level (Ministry of Environmental Ontario, 2014) and federally in the US (United States Environmental Protection Agency, 2021).

According to existing research and previous descriptions, feasibility studies and Environmental Assessment studies share many commonalities. For example, both studies review the project's impact and play essential roles in the decision-making. They have some overlapped research fields and could use the same evaluation methods. The Environmental Assessment usually covers a wider range of alignments and alternatives than feasibility study (Matsoukis, 2003). Therefore, for the LRT, EIS report is a more common process during planning stage. For some specific LRT projects, independent feasibility studies are performed (For example, Stage 2 Ottawa LRT Business Case Version 2.0, 2016). But in many cases, the EIA process includes the feasibility issues and makes a detailed analysis on these factors. Therefore, in this research, EA report and EIS are considered as the primary resources to evaluate the feasibility study for LRT projects.

In Canada, especially in Ontario, an LRT project is most commonly proposed by the municipal government. Therefore, the Environmental Assessment is also led by the local government; see for example (Region of Waterloo Rapid Transit Initiative Phase 2 Summary Report – Environmental Assessment Study, 2009; City of Edmonton Valley Line-Stage 1 Light Rail Transit Project Environmental Impact Screening Assessment Final Report, 2013). In some cities in the Greater Toronto Area (GTA) like Hamilton, Mississauga and the City of Toronto, the LRT project is

proposed by Metrolinx (Metrolinx, 2022), the quasi-governmental agency tasked with the oversight of transportation for the GTHA. In these cases, the EA for these projects is led jointly by Metrolinx and local governments; see for example (Spencer Environmental Management Services Ltd, 2013; Hamilton Light Rail Transit Environmental Project Report, 2017).

In the U.S, the Environmental Impact Statement is usually prepared by three organizations including Department of Transportation, Federal Transit Administration, and local transit organization. Examples of such studies include (Southeast Corridor Light Rail Transit In Dallas County, Texas, Final Environmental Impact Statement, 2003; East Link Final Environmental Impact Statement, 2011). In both countries, the Environment Impact Assessment studies involve a variety of consultants with different backgrounds. Participants include consulting companies, academic experts, and community members. These participants contribute their own experience and knowledge to the study and help to prepare the final Environmental Impact Statements (Kågström, 2016).

For each LRT project, some elements of the system may be clearly defined by the local conditions, but there is still a typical list of factors that should be contemplated (Hsu, Tsai, & Shiau, 2021). After reviewing a variety of EIS in both Canada and United States, the EIS in different cities follows a similar procedure which is outlined in the Environmental Assessment regulations. The following critical sections are used in the EIA process to best analyze the feasibility of the LRT projects.

Purpose and Demand

For the purpose and needs, the reports explore the general necessity and rationale for the project typically guided by existing regulations and planning documents. LRT projects are usually mentioned in a city's master plan or regional development plan. In those high-level planning documents, only initial assessments of demand and general objectives are outlined. In the EA and feasibility study, planners start from the guidelines from those documents and make further refinement by proposing detailed objectives and performing a series of studies to verify the feasibility of the LRT project. (Region of Waterloo Rapid Transit Initiative Phase 2 Summary Report – Environmental Assessment Study, 2009; Southeast Corridor Light Rail Transit In Dallas County, Texas, Final Environmental

Impact Statement, 2003; East Link Final Environmental Impact Statement, 2011; City of Edmonton Valley Line-Stage 1 Light Rail Transit Project Environmental Impact Screening Assessment Final Report, 2013).

Perhaps the most critical element contained in any transit feasibility study is the estimate of demand. Attracting riders to the system is necessary to:

- Generate revenues directly from the system that offset the operating costs and reduce the need for continuing government support.

- Reduce the use of personal auto travel which, in turn, reduces congestion helping to realize environmental benefits such as improved local air quality;

- Motivate development in the transit corridor, reducing decentralization, decreasing auto use, increasing active transportation and potentially allowing for land value capture in the corridor;

- The general perception of the system as a positively impactful contribution to the local community.

The demand for LRT projects is an essential factor that could affect the success of LRT projects (Kepaptsoglou, Stathopoulos, & Karlaftis, 2017). In existing impact assessment and feasibility studies, there are different methods used in EIS or EA reports to explain the demand for LRT projects. For example, in Dallas Southeast Corridor EIS (2003), researchers performed a review of the demographic, income, employment, travel behaviour, traffic accident, and transportation problems data to explain the necessity of the LRT project. But in the case of Seattle (2011), researchers referred to existing studies and planning guidelines to explain the necessity of the LRT projects. As has been discussed earlier, failure to attain ridership levels predicted in the planning process is regularly identified as problematic for transit projects.

Alternative Study

In the EIA process, researchers compare a variety of alternatives and evaluate the impacts – positive and negative – associated with those different options. The alternatives are chosen based on the local situation and there is no fixed standard as to the number or complexity of the differences among the choices. Often, alternative selections in transit projects will include an evaluation of multiple modes to determine the relative strengths and weaknesses of the technologies. For example, for the Region of Waterloo’s ION project, researchers initially considered Aerobus, Automatic Guideway Transit, Bus Rapid Transit, Commuter Rail, Light Rail Transit, Magnetic Levitation, Monorail, Personal Rapid Transit, Diesel Multiple Units, subway and No-build as different options (Region of Waterloo Rapid Transit Initiative Phase 2 Summary Report – Environmental Assessment Study, 2009). Beyond modal comparisons, alternative analysis may consider approaches other than infrastructure investments to achieve project goals. In Seattle (East Link Final Environmental Impact Statement, 2011) and Dallas (Southeast Corridor Light Rail Transit In Dallas County, Texas, Final Environmental Impact Statement, 2003), according to the local environment, evaluators also included Transportation System Management (TSM) / Congestion Management System (CMS) as non-infrastructure approaches; these were compared against expanding the existing Highway Network as alternatives for study corridor.

The study corridors for LRT projects are dozens of kilometers long and cover different land use and parts of cities. Given the diversity of conditions over the full alignment, in the EIA process, the corridors are separated into different sections which enable planners to perform a more detailed evaluation for alternatives. For each section, both different modes and alternatives routes are analyzed. Researchers review different related factors including technical background, geological and topographic factors, existing infrastructure and buildings, projected ridership and financial feasibility (Region of Waterloo Rapid Transit Initiative Phase 2 Summary Report – Environmental Assessment Study, 2009; Southeast Corridor Light Rail Transit In Dallas County, Texas, Final Environmental Impact Statement, 2003; East Link Final Environmental Impact Statement, 2011; City of

Edmonton Valley Line-Stage 1 Light Rail Transit Project Environmental Impact Screening Assessment Final Report, 2013). The results from each section are concluded and lead to the result for an alternative study to determine which is the best option for the study corridor.

Region of Waterloo Rapid Transit Initiative Environmental Assessment Study
Buffalo Light Rail Rapid Transit Project Construction: Environmental Impact Statement
Hamilton Light Rail Transit Environmental Project Report Addendum
Stage 2 Ottawa LRT Business Case Version 2.0
Valley Line LRT Stage 1 Environmental Impact Screening Assessment (Edmonton)
Southeast Corridor Final Environmental Impact Statement (Dallas)
Arizona Passenger Rail Corridor Study Tucson to Phoenix Environmental Impact Statement
East Link Final Environmental Impact Statement (Seattle)
Life Cycle Environmental Impact of Houston METRO System – Evaluation of Electric Alternatives
Final Environmental Impact Statement East Urban Corridor – San Diego Region

Table 2-1 Light Rail EIA Reports

Impact Assessment and Mitigation

Impact Assessment Process is the most critical section in EIA process which directly affects the decision-making process. All reviewed EIA listed in Table 1 include an Impact Assessment and Mitigation section.

The impact analysis reviews both negative impacts and potential benefits along the corridor. Environmental Impact assessment focuses on identifying the impact on valuable environmental assets such as water resources, animal habitats, air quality, wetlands, and noise. In addition, the environmental feasibility study usually also includes an evaluation of cultural heritage along the corridor. Typically, planners establish a baseline condition for these valuable assets and then forecast projected, potential impacts. If obvious negative impacts are identified, an effective mitigation plan will be needed.

In this section, the EIA also outlines the indirect impact like economic growth, employment opportunities and future urban development along the corridor. In the short term, it is easy for planners to project and estimate because the impacts are obvious. For example, the construction of LRT could affect the traffic and business along the corridor. However, the Light Rail system could stimulate the economy along the corridor in the long term.

This uncertainty is often a critical component that, as noted earlier, is strongly interconnected with ridership and the “success” of the project. Forecast changes in economies and land use certainly depend on the quality of the transit investment, but also are impacted by forces beyond the control of local planners. As local economies evolve, transit corridors may be more or less desirable locations for residents and firms. Similarly, changing foci in local economies may attract residents (and the firms that employ them) with different demographics that may have very high or very low propensity to use transit. The very fact that these external forces influence the likelihood of transit systems’ success is the primary motivation for exploring how they ought to be considered in EIS / Feasibility assessments.

In reviewing previous EIS, a trend is observed that suggests that feasibility reports usually only state a positive expectation because Light Rail Transit projects' impact on these areas. The following section demonstrates how recently constructed Light Rail Transit Systems have been assessed relative to pre-construction predictions.

2.5 Review Existing Light Rail Transit Projects

Even though feasibility studies have included plenty of different perspectives, they still cannot guarantee the success of Light Rail Transit projects. There are many embedded risks, and existing projects have encountered many problems.

Research suggests that one of the most severe and direct risks for very large, public sector investments like LRT is cost overrun (Flyvbjerg, 2007). According to Flyvbjerg's research (2007), 58 urban rail projects were reviewed, including both heavy and light rail projects. The result showed that more than 75% of urban rail projects had cost overrun issues. The projects have cost escalations of at least 24%, and 25% of these projects have an escalation of more than 60%. In the United States, reports from FTA revealed that the average cost overrun for 21 projects completed between 2003 and 2008 was 40.2% (Federal Transit Administration, 2016). In Canada, there is a cost overrun news for almost every existing LRT project. Light Rail Transit projects in the Region of Waterloo, Ottawa, Edmonton and Calgary all encountered cost overrun issues (Ottawa's LRT Project Over-Budget: BULLDOG STUDY, 2021) (Edmontonians for Responsible Urban Public Transit, 2022)(MacVicar, 2022).

Another risk associated with LRT projects is overestimated demand. Research showed only 10% of LRT projects correctly estimated their real passenger demand. Actual ridership is 50.8% lower than forecast (Flyvbjerg, Cost Overruns and Demand Shortfalls in Urban Rail and Other Infrastructure, 2007). In evaluations of Buffalo, Portland and Sacramento, the actual ridership was 59%, 54%, and 71% lower than forecast at various stages after system opening (Black, 1993). The lower ridership leads to lower fare revenues, decreasing local project benefits and increasing local financial support the operation of LRT.

In North America, massive transit projects like LRT are usually funded through combinations of different levels of government and, in some cases, the private sectors. Given the relatively high operating costs, due to wages and benefits paid to operators, transit systems throughout North America regularly do not generate sufficient revenue from fares to cover their operating costs. As such, local governments often point to LRT's indirect benefits including land use development and economic improvements along the corridor, as positive outcomes that outweigh the financial subsidies for the systems.

From a planning perspective, the development related to the transit system is also known as Transit-Oriented Development (TOD). TOD aims to promote high-density development around transit stations and active transportation (Institute for Transportation & Development Policy, 2015)(Thomas & Bertolini, Defining critical success factors in TOD implementation using rough set analysis, 2017). The TOD concept is predicated on the presumption of transit investments motivating development and economic activity along an LRT corridor. However, the empirical data presented in the research not only shows mixed results, but also fails to arrive at a consensus on how the impacts of LRT investments should be measured.

First, there are still some debates on the extent of the impact a transit investment may have. More specifically, practitioners and researchers debate the distance around a station within which new development should be considered as TOD. The range can vary from 400 meters to 1000 meters based on different standards (Bolleter & Ramalho, 2019) (Cervero & Dai, BRT TOD: Leveraging transit oriented development with bus rapid transit investments, 2014). Moreover, there are different definitions of high-density development. For example, in Denver, the high-density urban center has a density of only 24 units per hectare (Ratner & Goetz, 2013). However, the density range in Europe is usually between 30 and 100 units per hectare (Institute for Transportation & Development Policy, 2015).

From an economic development perspective, the TOD concept does not perfectly service all types of economic activity. The TOD stimulates economic activities by improving accessibility near the transit stations. Transit Stations, as the nodes of the transportation network, become more attractive to economic activities that need face-to-face and shoulder-to-shoulder experiences (Bertolini, Curtis, & Renne, 2012). A Phoenix study shows that the LRT project strongly promotes retail, service, and knowledge industries (Credit, 2018). For other industries, the LRT project could have a very limited impact. Returning to the discussion above, a city in which the service or retail sectors are naturally increasing, the introduction of an LRT may generate more positive results than a similar city where these transit-friendly economic sectors are declining. From a land use and real estate market perspective, the TOD concept also does not guarantee changes. First, due to land costs and density requirements, apartments and condos are the most common housing types near LRT stations. High-rise condos and apartments have a relatively higher construction cost, which leads to a higher housing price. These relatively (compared to low density, greenfield construction) higher construction costs may generate higher prices for which little demand exists. In existing studies, researchers reveal that high housing price may be inconsistent with the real land values, as demonstrated by purchasers (Wen & Goodman, 2013, p. 11). This reality has been observed with disparate outcomes for TODs in various cities. The property value in many cities (Sheffield, Sacramento, San Diego, and Miami) did not have an obvious change due to the construction of LRT (Institute for Transportation & Development Policy, 2015) (Powe, Dziauddin, & Alvanides, 2015) (Yu, 2020). The example in Minneapolis also shows that the completion of the LRT project had minimal impact on the land use changes and urban redevelopment (Hurst & West, 2014). The literature on TOD and the impact of transportation projects on urban environments continues to evolve. Muller (2005) defines an era of urban freeway investments that were largely seen to disrupt and, in some instances, devastate existing cities for which Detroit is often cited. In the 1950s, in the City of Boston, the Interstate 93 was constructed as an elevated freeway – the Central Artery – that divided neighborhoods. In the late 1990s and the early 2000s, the Central Artery was reconstructed as a tunnel, reconnecting the city core. As major transportation investments are now being contemplated, the impact they will have on cities, and particularly the city's more vulnerable residents, is considered more completely. Often, transit investments are predicted to provide lower investment cost, lower operating cost mobility for low-income populations who typically have lower car ownership and greater dependence on public

transit services. For higher income earners, existing studies confirm that residents are typically willing to pay more for the accessibility and attractive urban environment (Li , Joh, Lee, Kim, & Woo, 2015). What has become a more commonly observed concern is the dichotomy of transit providing greater accessibility but, concurrently increasing housing prices which preclude low-income residents to own or rent near to the system. Simply, the high housing price in the station surrounding area pushes low-income households to choose between affordable housing and affordable transportation (Thomas & Bertolini, Defining critical success factors in TOD implementation using rough set analysis, 2017) and leads to equity issues for LRT projects.

The previous examples reveal that while intended to be comprehensive, existing feasibility studies are forecasting outcomes that are influenced by great complexity, uncertainty, and in some cases dynamic conditions beyond control of the planning agencies. In many aspects, the performance of the LRT project is despite the technical requirements unpredictable. Existing studies failed to explain why similar LRT projects could have such different impacts. There must be some critical elements missing in the existing feasibility study methods. In this work, I investigate the possible improvements that may be achieved by considering information derived from an assessment of initial conditions and urban trajectories within cities.

Chapter 3 Research Methods

3.1 Chapter Outline

Chapter 2 presents the literature and existing research outcomes on the major themes of this thesis. The chapter explored the challenges of auto-oriented cities and the history of LRTs with an emphasis on the evolution of LRT in urban transportation development, especially in mid-sized cities.

In addition, Chapter 2 also introduced the existing feasibility study method for LRTs and review a list of EIA reports. Finally, chapter 2 identified the strength and weakness of the existing feasibility studies. A critical takeaway from Chapter 2 is that most current studies do not include initial urban growth background as an essential factor that could impact the outcome of the LRT project.

To address this research gap, this chapter primarily focuses on interpreting the research methodology:

Introducing the two selected cities and the related Light Rail Transit Projects;

Explaining the logic of the selection the study areas;

Providing a systematic review of the documented data and sources;

Clarifying the analytical process of understanding the urban growth background.

3.2 Research Method

This thesis uses a case study approach to explore how the subject cities or regions' initial background – in terms of their trajectories (or trends) in population, employment, and land use – impacts on the Light Rail Transit project in cities. Ultimately, the hypothesis to be tested is whether the trends in these variables may have been predictive in assessing the likelihood of the LRTs achieving their transportation and broader system goals.

As noted by Crowe, the case study approach allows in-depth, multi-faceted exploration of complex issues in real-life settings (Crowe, et al., 2011). It is a widely used qualitative research method for social studies with plenty of strengths in research depth, high conceptual validity, understanding of context and process, understanding of the cause of phenomenon and links between cause and outcomes, and fostering new hypotheses and research questions (Flyvbjerg, Case Study, 2011).

The case study approach perfectly fits this study's research objectives for two reasons. First, the case study could provide valid data support to present the initial background's impact on LRT project. For this research, a comparative case study is designed to select two similar cities with different urban growth trajectories. By analysing how the urban growth trajectories are different and how different trajectories could affect the decision-making process, this research could explore the relationship between urban growth trajectories and the success of the LRT.

Secondly, the case study approach permits a focused and in-depth examination of various facets within the chosen cases, illuminating both the intricate details and the broader implications of the research problem. In this research, a detailed comparison is conducted of the selected case study cities, the Region of Waterloo, and the City of Buffalo. The comparison will focus on the initial urban development trajectory which includes population trends, social-economical development trends and other aspects and the feasibility study for the LRT projects.

A systematic review was conducted by analyzing planning documents including Region Planning Plans, Environmental Impact Studies, Regional Transportation Master Plan, alongside the quantitative data to verify the importance of including urban growth trajectory analysis in the feasibility studies for LRT projects.

3.3 Introduction to Case Studies and LRT projects

3.3.1 Case Study City Selection

To select the proper cases for this research, a document research methodology was applied. According to the definition mentioned in the previous section, the mid-size cities in this research are selected mainly based on the population. The population of mid-size cities are about 200,000 to 300,000. In the first round, a great number of LRT projects in the North America cities were scanned based on the cities size and only LRT in the mid-size cities will be selected as the candidates for the case study.

In this study, ten mid-sized cities in North America have been reviewed and analyzed for the scanning process. This research critically and thematically reviews the Environmental Impact Assessment for all the ten mid-size cities to gain a greater understanding of their populations, economy development and urban growth challenges. Region of Waterloo is chosen as the one of the cases because it is very familiar to the research team and this research is supported by University of Waterloo. After the Region of Waterloo was selected, among other candidates, City of Buffalo is chosen to be the other case study cities.

3.3.2 Why City of Buffalo and Region of Waterloo

As with any comparative research, one needs to identify case studies that share sufficient similarities that allow for a direct comparison, while controlling for those elements that are inherently different. When a study is evaluating the similarities of cities in terms of their transit ridership, land use evolution, or economies, the assessment ought to include the following. Are the cities similar climatologically, as weather and temperature tend to influence the likelihood of using transit? Similarly, do the cities share common economic foundations in terms of the types and distribution of employment in the areas?

Cities with similar land use densities are more readily compared than those with substantively different urban form. From a social perspective, comparator cities ought to share similar cultures and societal norms, ensuring relatively consistent behaviours in response to economic or social cues.

Geographically, the cities are situated around 150km apart, resulting in very similar climates for both areas. They both experience a humid continental climate characterized by warm summers and cold winters. The Region of Waterloo exhibits a mean yearly temperature of 7.6 degrees Celsius, with an annual temperature range spanning from -10 to 27 degrees Celsius (Environment and Climate Change Canada). The annual precipitation level for the Region of Waterloo measures at 974 millimetres (Environment and Climate Change Canada). Due to the influence of the lake effect from Lake Erie and Lake Ontario, the city of Buffalo experiences slightly more snowfall during winter and higher winter temperatures compared to the Region of Waterloo. The City of Buffalo registers a mean yearly temperature of 9.4 degrees Celsius, with an annual temperature range ranging from -6 to 26 degrees Celsius (National Centers for Environmental Information;National Oceanic and Atmospheric Administration). Moreover, the annual precipitation level for the City of Buffalo is recorded at 1087 millimetres (National Centers for Environmental Information;National Oceanic and Atmospheric Administration) .

Throughout history, the manufacturing and wholesale sectors have held significant importance for both cities, playing a pivotal role in shaping their respective economies. Despite facing challenges such as population redistribution and economic recessions, the City of Buffalo managed to sustain a considerable presence in these industries. As of 1980, the manufacturing industry accounted for 27% of employment opportunities (United State Census Bureau), while wholesale held 16% of the job market. Similarly, the Region of Waterloo also heavily relied on the manufacturing and wholesale sectors, as evidenced by the 1981 census results. At that time, approximately 37% of employment opportunities originated from the manufacturing industry, while wholesale contributed 17% of the job market (United State Census Bureau). Even as time progressed, manufacturing and wholesale continued to be significant sources of employment for both regions. As of 2001, manufacturing still provided 26% of employment opportunities in the Region of Waterloo (Statistic Canada).

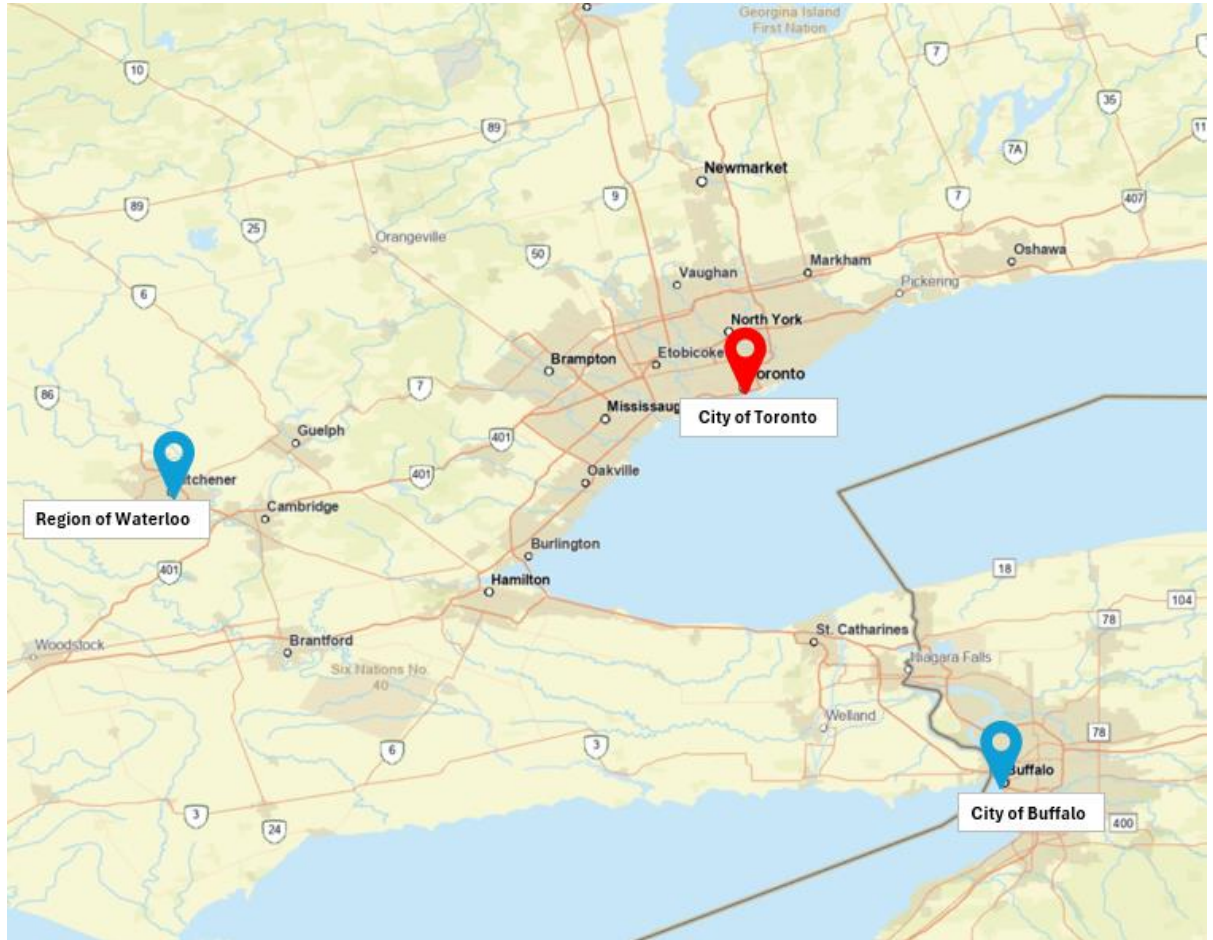


Figure 3-1 Location of Region of Waterloo and City of Buffalo (Created by Author)

From a political perspective, though geographically proximate to key political centers and mega cities, neither City of Buffalo nor Region of Waterloo are the capital city for its state or province. In New York State, where the City of Buffalo located, Albany is the capital city, and the New York City is the primary mega city with distinct world-wide reputation (Campbell & Paul Joseph , 2023) . In Ontario, the City of Toronto is not only the capital city but also the biggest city. In addition, Ottawa is the capital city for Canada (Hillmer & Bothwell, 2021). In general, those mega cities and cities with special roles could attract more political attention that may affect the major projects like the LRT. In

this research, the City of Buffalo and Region of Waterloo are typical mid-size cities with North America standard without special political interest.

From public transit operation perspective, for both case study cities, the public transit operator (Niagara Frontier Transportation Authority & Grand River Transit) are regional transit operators, which means the LRT service in both case study cities are part of the regional transit network and could interact with whole metropolitan areas not only the city center. However, the two selected LRT projects received different support from Provincial/ State governments. For the Region of Waterloo, when the LRT was planned, the Federal and Provincial Government has already recognized the importance of developing rapid transit and provided a series of supportive policy for the LRT project (Ruffilli, 2010). For the City of Buffalo, even though the LRT project also received funding from the State and Federal Government, the high-level government failed to recognize the potential impact that LRT could have on a city's development. Therefore, there were almost no supportive policies followed up with the LRT development in Buffalo.

However, their demographic trends have taken different paths over the years. The City of Buffalo experienced a decline in population starting from the 1950s, after reaching its peak. By the 1980s, the population had decreased significantly, plummeting from 580,100 in 1950 to 359,700 (Statistic Canada). On the contrary, the Region of Waterloo witnessed a contrasting pattern as its population showed a consistent increase since the 1980s. Over time, the population rose from 289,000 to 587,165 by the year 2021 (Statistics Canada, 2021). In both case study cities, they all encountered a decline in their city core. In the City of Buffalo, with a decline city wide population, the city core encountered an even more rapid population decline than sub-urban area. However, in the Region of Waterloo, the declining in city core was also sever. The downtown area started to lose its competitive role in retail and business since 1970s and a variety of downtown revitalization plans were proposed to improve the competitiveness for downtown area from housing, business, and environmental perspectives (Borovilos, 2014) . Meanwhile, as the population kept growing, new-coming population added a great pressure to extend the city boundary.

3.3.3 People's Attitude on Public Transit

In this research, before exploring the performance of the Light Rail Projects, it was recognized that the people's attitude on public transit is a significant factor that contribute to the city initial background. Different people's attitude on public transit could greatly affected the potential success of the LRT projects. Cities where public transit is more widely accepted and valued tend to create a more solid customer base for the new transit system which stimulates the success of LRT projects. Several studies have highlighted that a series of factors can influence public acceptance of transit systems, including the quality of service, gas prices, availability of competing transportation options, and patterns of land use. (Geneviève , et al., Invest in the ride: A 14 year longitudinal analysis of the determinants of public transport ridership in 25 North American cities, 2018; Gregory , et al., Why has public transit ridership declined in the United States?, 2022).

For the City of Buffalo, the construction of the interstate highway system in the 1950s and 1960s greatly accelerated automobile adoption in the U.S., reshaping urban and suburban landscapes. This extensive network made driving more convenient, leading to a surge in car usage (Janushewski, 2014). The auto-dominant travel behavior was also noticed by Paul Schmick's research (1996) h that started in 1950s. In the United States, the average automobile per capita increased from 0.3 to 0.6 from 1950 to 1980. Then the United States entered a saturation status of the car ownership. At the same time, the Canadian's automobile ownership was 0.1 car per person lower which leading to a 15-20% less driving (Schimek, 1996, p. 6).

In addition, when the LRT was proposed in 1970s, the gasoline price fluctuated violently due to two energy crises in 1973-1974 and 1979-1980. Comparing with Canada, the vehicles in the United States were about 20% less fuel efficient and American's travel behavior made them more reliable on vehicles (Schimek, 1996). Considering the high gasoline prices, the introduction of LRT project became even more attractive cause it could provide an alternative option and could reduce the gasoline consumption. However, the gas price greatly dropped between 1982 and 198 (Schimek, 1996) 6. According to the findings from existing research, the existing behavior and low gas price when the LRT completed would be more likely to undermine the performance of the LRT project.

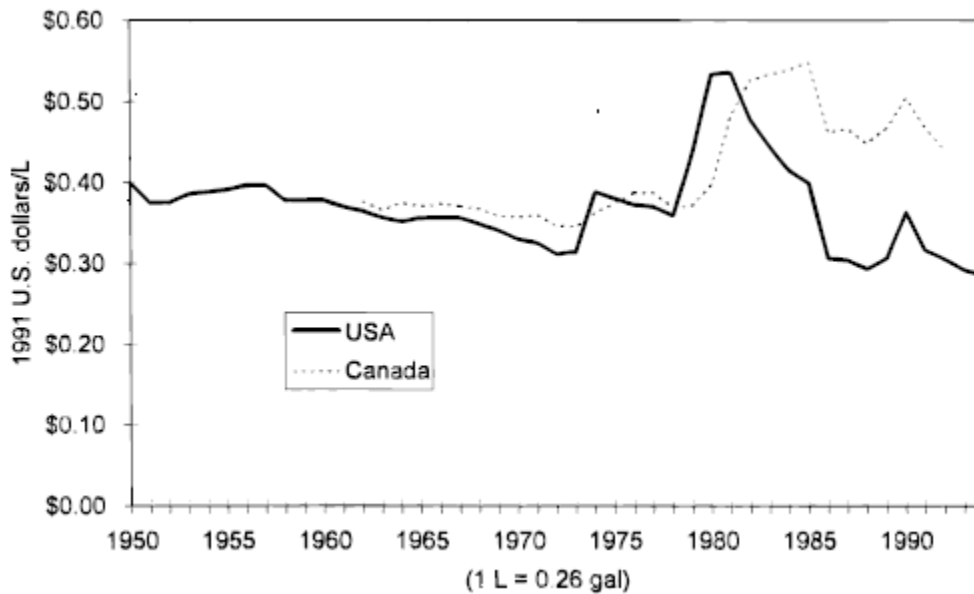


Figure 3-2 Consumer Price of Gasoline (Schimek, 1996, p. 4)

In the Region of Waterloo, the situation was quite different. From history, Canadian showed a higher acceptance on public transit than Americans (Schimek, 1996). In recent decades, the public transit ridership increase had greatly outpaced the population growth, which means increasing population wasn't the primary reason for the ridership increase (Planning Research and Analytics, 2015). Renovated built environment, high quality transit services and higher portion of students and new immigrants are the key factors. And these are also factors that affect the public attitude on the public transit (Geneviève , et al., Invest in the ride: A 14 year longitudinal analysis of the determinants of public transport ridership in 25 North American cities, 2018; Gregory , et al., Why has public transit ridership declined in the United States?, 2022; Taylor, Miller, Iseki, & Fink, 2009). Therefore, the fast-growing ridership showing an increase public acceptance on the public transit. Public's high acceptance on transit stimulate the high demand for transit services allowed Grand River Transit to introduce high-frequency Express Service in some corridors (Farahani, 2008). Gas prices in Ontario exhibited an overall upward trend from 2011 to 2024, despite brief periods of decline. From 2019 when the LRT first opened, prices resumed their rise, culminating in a sharp spike in 2022, nearly doubling from previous levels (Statistics Canada, 2024). The high gas price could increase the cost of driving and make public transit more attractive to the public.

3.3.4 Macro Socio-Economic Context

The broader macro-historical context, encompassing significant shifts in industry, technology, and socio-economic trends, plays a pivotal role in shaping a city's initial conditions and development trajectory. This overarching context sets the stage for a city's growth or decline, significantly influencing the success of urban infrastructure projects like Light Rail Transit (LRT). Understanding these macro-level forces is crucial as they profoundly impact local economic health, population trends, and, ultimately, the effectiveness of such projects.

In the case of the City of Buffalo and the Region of Waterloo, their respective macro-historical contexts diverged dramatically at the time of their LRT introductions. Buffalo's LRT was developed during a period marked by the relocation of manufacturing jobs and the city's consequent inclusion in the Rust Belt (Duryea, 2015, p. 15). This context of deindustrialization brought significant economic challenges, including job losses, population decline, and urban decay, all of which negatively impacted the LRT's potential success. On the contrary, the Region of Waterloo embarked on its LRT project during the rise of fast-developing high-tech industries. This context fostered economic growth, population influx, and a vibrant community, creating fertile ground for the successful implementation of the LRT (C40 Cities Climate Leadership Group, C40 Knowledge Hub, 2019). The stark contrast between these two cities allows this research to explore how the macro social-economic context can affect the outcomes of urban development projects like LRT and highlighted the importance of including contextual information as part of a city's initial conditions.

3.3.5 Light Rail in the City of Buffalo

After a detailed review of the proposed light rail project and available alternative from a variety of perspectives including, financial feasibility, cost control, construction, operation noise; most substantively, there was significant skepticism that the stated benefits would be achieved .Even though there were concerns, the rapid transit project was approved (U.S. Department of Transportation Urban Mass Transportation Administration). The LRRT system was estimated to cost \$474 million (1974 value), with more than 80% expected to be a federal investment. As the proposal

developed, the expected cost grew rapidly, primarily due to the inflation of the late 1970s. As a result, even the 20% local contribution for the project became a huge financial burden for the city, and the plan was changed. After revision, the LRT route only reached the University of Buffalo South Campus on the city boundary.

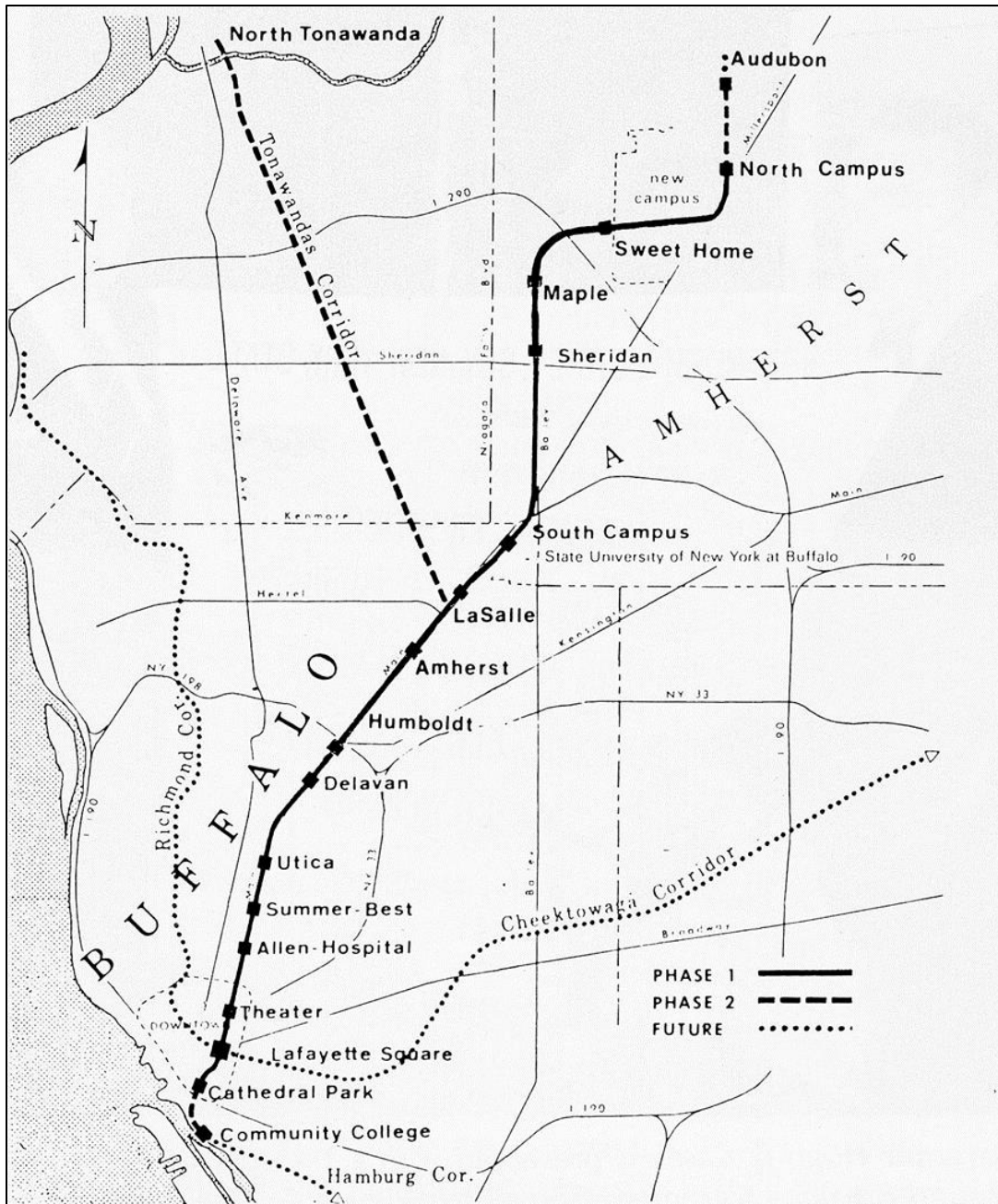


Figure 3-3 LRT in City of Buffalo (Final Environmental Impact Statement Buffalo Light Rail Rapid Transit, 1977)

This revised Light Rail project was proposed with a length of 6.4 miles (10.3 kilometres). The construction of the LRT started in 1979. The surface portion of the system was opened in 1984, and the underground part was opened in 1985. The LRT line was extended to the University of Buffalo in 1986. About 80% of the tracks and eight stations between the State University of New York South Campus and Tupper Street were underground. The remaining 20% of the Tupper Street and Buffalo's Memorial Auditorium is on Main Street's surface in downtown Buffalo. At the time of opening, there were 15 stations; the Theater station was closed in 2013, and the DL&W station will replace the Special Events Station. Public transit service has been provided by the Niagara Frontier Transportation Authority (NFTA), both buses and the LRT services.

Year	Estimated Ridership	Annual Fare-Box Revenue (\$)	Annual Cost (\$)	Fare Recovery Ratio
1982	37,500	\$ 14,250	\$ 18,516	76.96%
1983	45,000	\$ 17,100	\$ 21,001	81.42%
1984	48,000	\$ 18,240	\$ 21,994	82.93%
1985	50,400	\$ 19,152	\$ 22,789	84.04%
1986	51,000	\$ 19,380	\$ 22,988	84.30%
1987	51,600	\$ 19,608	\$ 23,187	84.56%
1988	51,900	\$ 19,722	\$ 23,286	84.69%
1989	52,500	\$ 19,950	\$ 23,485	84.95%
1990	53,100	\$ 20,178	\$ 23,683	85.20%
1991	53,400	\$ 20,929	\$ 23,783	88.00%
1992	53,700	\$ 20,406	\$ 23,882	85.45%
1993	54,300	\$ 20,634	\$ 24,081	85.69%
1994	54,600	\$ 20,748	\$ 24,180	85.81%
1995	55,200	\$ 20,976	\$ 24,379	86.04%

Table 3-1 Comparison of NFTA Operation Cost and Revenue :1982 (all numbers in thousands)

Ridership Reduction	Annual Ridership	Annual Revenue	Annual Cost	Recovery Ratio
-10%	49,680	\$ 18,878	\$ 24,379	77.44%
-20%	44,160	\$ 16,781	\$ 24,379	68.83%
-50%	27,600	\$ 10,488	\$ 24,379	43.02%

Table 3-2 1995 Estimated Reduce Ridership, Constant Fares and Service (All numbers in thousand)

According to the EIA report (1977), the estimated annual ridership was expected to be 37,500,000 in 1982 and gradually increased to 55,200,000 until 1995. It was also estimated that the LRT project could have a farebox recovery ratio of over 76% for 20 years after the system opened. As calculated in the EIA report even if the ridership was overestimated by 50%, there would be still a 43.02% fare recovery ratio without service reduction.

Since the first construction of the Light Rail System, there has been plenty of discussion about expanding the light rail network. Considering the limited ridership performance on the existing network and the high construction cost for the new system, no further investment was available to support the potential expansion of the light rail system until now.

3.3.6 Light Rail in Region of Waterloo

After many years of planning and public debate, the Light Rail Transit Project, named publicly as the ION, was approved by the council in 2011 (Planning, Development and Legislative Services, Region of Waterloo) and construction was started in 2014. It was estimated that the project would cost \$818 million Canadian Dollars and the Region's share was \$253 million. The project

construction was expected to be three years; several unexpected construction interruptions delayed the opening until the system went into operation in 2019.

The LRT route in the Region of Waterloo starts from the Conestoga Mall in the northern part of Waterloo and finishes at Fairview Mall in Kitchener. The route is 19 kilometers and spans the Region's Central Transit Corridor (CTC). There are 19 stations in total, and 6 of these stations serve one direction. Public transportation in the Region of Waterloo is overseen by Grand River Transit, as part of the regional government. GRT provides bus services for the Region. GRT and the Region contract with Keolis corporation that operates the LRT. To the customer, the system is fully integrated, with a single fare payment system and free transfers (within 90 minutes) between bus and rail.

According to the EA report, the estimated daily ridership was expected to be 31,000 in 2014 and will increase to 63,000 in 2031 (Aecom, Hatch Mott MacDonald, Region of Waterloo, 2009). In addition, the EA report also expected that investment on the Light Rail project will also help to attract the ridership for the conventional transit system. The initial project in the Region comprised the 19km of LRT described here and an additional 18 km of express bus service connecting the rail southern terminal at Fairview mall to the city of Cambridge. The initial LRT planning included a second phase of the project in which the southern portion of the route would be converted from BRT to LRT. The second phase of the LRT is currently still being developed.

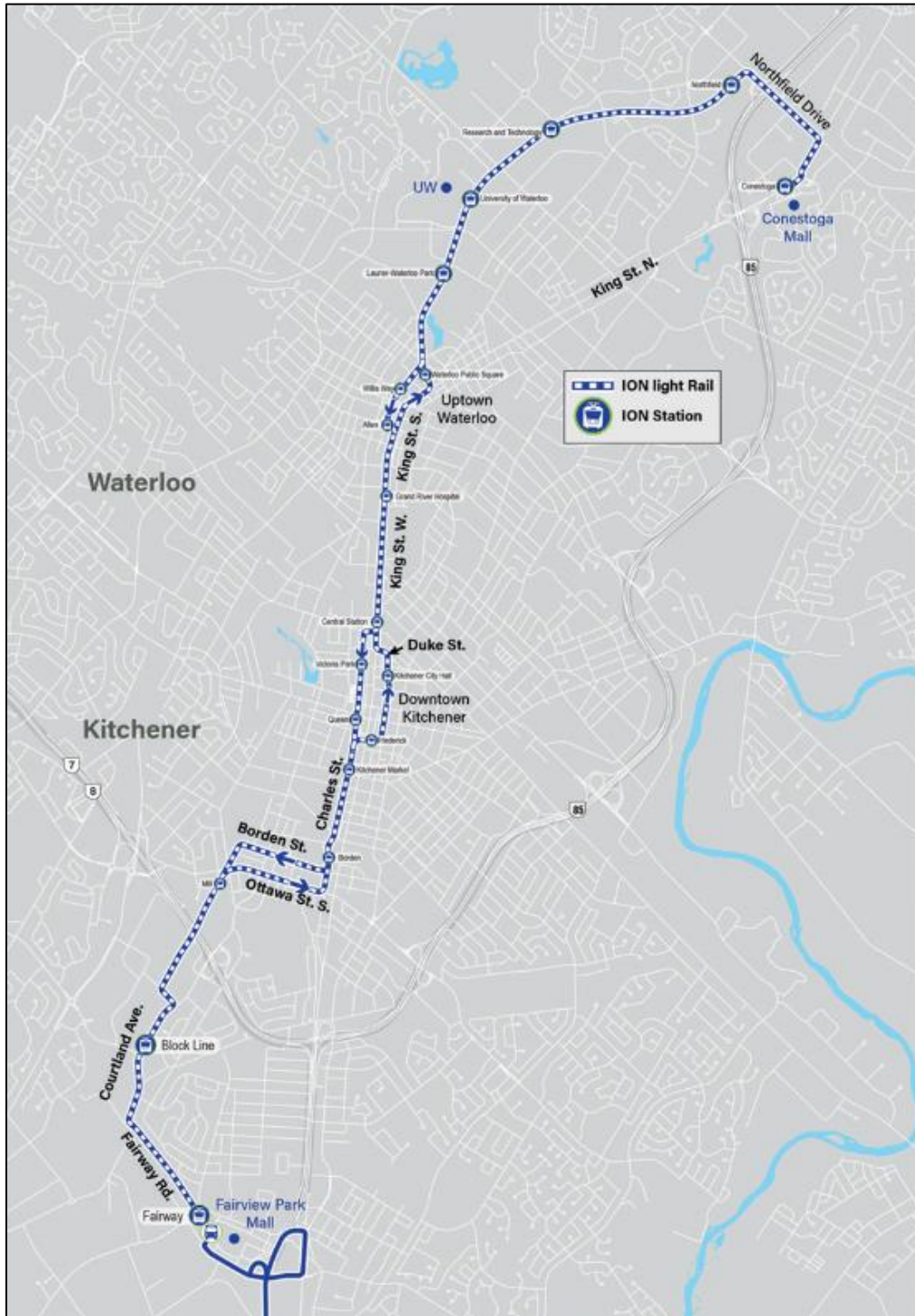


Figure 3-4 LRT in Region of Waterloo (Grand River Transit, 2017)

3.4 Data Collection and Analysis Method

3.4.1 Ideal Data Collection Process

In an ideal scenario, this study aims to meticulously address the shortcomings of existing feasibility research. By delving into a multifaceted analysis encompassing population dynamics, economic variables, and sociocultural factors, the study aims to delineate distinct urban development trajectories in the two selected case study cities. The analysis should be juxtaposed with the planning objectives outlined in the preceding feasibility reports. This will enable the evaluation of the performance of LRT projects within these two cities in alignment with the established planning goals. In this context, the data to be collected for the two case study cities should include the following:

- **Demographic**

In the EIA report of both cities, population data serves as the primary focus of investigation. Within the environmental assessment reports, both cities have conducted analyses and projections regarding number of total populations, demographic characteristics, and population projection. However, within these two case study cities, the analysis of population extends beyond the city, taking into consideration the transit corridor areas and specific focal neighborhoods. Considering the above, for this study, an ideal set of population data should encompass the following elements for each census tract within the city: total population count, demographic characteristics (gender distribution, age distribution, ethnic composition), population density, income levels, and unemployment rates. In this research, a census tract level of data accuracy is important because it allows this research to compare the transit corridor and other areas of the case study city. Furthermore, this dataset should span a period of twenty years following the completion of the LRT, allowing for an exploration of population changes in the post-LRT construction era.

- **Economic and land use**

In the Environmental Impact Assessment (EIA) reports of the two selected case study cities, a diverse array of indicators has been employed to characterize the economic development status, particularly within specific focal areas such as the city center and the LRT corridor

sections. Within the EIA reports, various metrics, including the number of companies and institutions across different industries, employment statistics within diverse sectors, household income data, among other indicators, are utilized in conjunction with a macroeconomic developmental framework to delineate the economic development landscape of the cities. Therefore, in an ideal scenario, this research should aim to collect data pertaining to the number of companies in various industries, employment distribution, and household income data within each census tract over a period of twenty years following the completion of the LRT. These datasets would be instrumental in contrasting and describing the economic development status within the LRT corridor and across the city as a whole. Furthermore, they would be juxtaposed against the economic development forecasts delineated in the Environmental Impact Assessment (EIA) reports to confirm the role of the LRT in stimulating economic growth.

In a manner parallel to the assessment of economic development, the Environmental Impact Assessment (EIA) reports for both case study cities articulate a multitude of planning objectives concerning land use. While the specific goals may vary slightly between the two cities, the overarching aim is to foster the concentration of commercial activities within the LRT corridor and anticipate that the completion of the LRT will deter the decline of the downtown areas in both cities. Notably, in the Region of Waterloo, their Regional Growth Management Plan underscores the desire for the LRT project to provide better support for the development of high-density mixed-use projects within the Central Transit Corridor while effectively guiding the rational distribution of the population. Thus, in an ideal scenario, this research should endeavor to collect data encompassing the vacancy rates of commercial structures, the quantity, and scale of various types of new development projects within each census tract city-wide, over a twenty-year period following the LRT's completion.

- **Transit Behavior**

In terms of travel behavior data, during the planning phases, the Environmental Impact Assessment (EIA) reports for both case study cities have put forth specific assessment metrics such as ridership and fare-recovery ratio. Ideally, it would suffice to collect

operational data corresponding to the period following the completion of the LRT. Furthermore, the influence of the LRT on the travel habits of the public has been a significant evaluation criterion in the EIA reports during the planning phase. Typically, the measurement of public travel behavior is conducted by consulting firms through surveys in questionnaire form and subsequently analyzed and compiled. In an ideal scenario, this research should aim to gather similar research reports from different time periods and employ comparative analysis to deduce the impact of the LRT project on public travel patterns.

Although the preceding sections have outlined the ideal scenario wherein this research emphasizes the need for diverse data types, the actual implementation of this study has encountered several data limitations. Regarding the City of Buffalo, the LRT project was completed in 1984, which necessitates the collection of data spanning the period from 1984 to 2004. Given that this data pertains to a timeframe of 20 to 40 years ago, it is important to note that certain specific data points may not be readily accessible through public channels. Similarly, for the Region of Waterloo, where the LRT project was completed in 2019, it is not possible to obtain data for the full 20 years following the project's completion. These temporal limitations underscore the challenges associated with accessing historical data and the need for careful consideration of data availability and comparability in the research process. "Unlike real-world planning and assessment reports, which can undergo separate research and analysis for individual subsections, given the scale of this project, it relies heavily on publicly available data throughout the research process. This approach is necessitated by the practical constraints inherent in studying complex urban development and transportation projects, where comprehensive datasets are often the primary source for analysis. Due to various constraints, this study, while adhering to the ideal scenarios, this research has made the following choices by amalgamating the available data from the two case study cities:

3.4.2 Data Source

3.4.2.1 City of Buffalo

For the City of Buffalo, the socio-economic data are primary from following two sources, Decennial Census Product from U.S. Census Bureau and Integrated Public Use Microdata Series (IPUMS). Decennial Census is held by the U.S. Census Bureau every ten years. In this research, data from the

1960 to 2000 census was collected. The decennial census products provide the city-wide demographic, transportation, employment, and income level data. The Integrated Public Use Microdata Series, often abbreviated as IPUMS, is a valuable resource and data initiative that provides researchers and analysts with access to extensive microdata from various population and housing censuses, as well as other surveys conducted in the United States and around the world. IPUMS is hosted and maintained by the University of Minnesota's Minnesota Population Center. This resource is widely used in academic research, policy analysis, and social science studies to explore various aspects of population and housing dynamics, labor markets, educational attainment, and much more (IPUMS USA, 2023). The IPUMS provides various high-precision social-economic data from over sixteen federal censuses (Integrated Public Use Microdata Series (IPUMS), 2022) .

For demographic data, as Decennial Census products primarily focus on city-wide data, the IPUMS database has become an ideal supplementary data source. This research utilized the IPUMS database as a backup data source to collect the population data by census tract. The IPUMS database can provide population data including number of populations, population character and area by census tract from 1970 to 2000. The high accuracy level data are used to track the changes in the LRT neighbouring communities. The data collected through IPUMS followed the Federal Census standard, ensuring quality (Integrated Public Use Microdata Series (Integrated Public Use Microdata Series (IPUMS), 2022) .

For economic data, the decennial census can provide broad-level information such as employment distribution, per capita income, and household income status only at the city-wide level. More granular economic data is not typically available through these decennial census products. In the context of this research, a deeper understanding of economic changes in the City of Buffalo and the LRT corridor following the completion of the LRT project relies on existing research studies rather than direct economic data indicators.

For the transportation section, the travel behaviour data are available in the Decennial Census Products. Decennial Census Products do indeed provide data on the distribution of commuting modes chosen by individuals every ten years. The ridership data for the Light Rail System is collected from the official website of Niagara Frontier Transportation Authority (NFTA). Since fare-recovery ratios are not publicly available as a distinct data category, this study cannot collect direct data on this metric. However, it is possible to indirectly infer ticket revenue by examining ridership data. From the NFTA website, there are also shapefiles for the LRT routes and Stations which can be used to build project related maps.

3.4.2.2 Region of Waterloo

For the Region of Waterloo, like the City of Buffalo, Canadian population census data serves as the primary source of data for this study. It offers a wide range of data types, including population counts, demographic characteristics, per capita and household income, employment statistics, as well as commuting modes. Unlike the United States, where the population census occurs every ten years, the Canadian national census program is held every five years. In the Region of Waterloo, the Light Rail System started its operation in 2019. However, at the time of this research, the results of 2021 census program have not been fully published. However, from the Regional Growth Management Plan (2003) and EIA report (2009), it is shown that LRT is one of the multiple methods to manage the growth within the Region of Waterloo. Many other growth management policies and supportive methods have been applied to the Region since then. Therefore, in this research, the data collected from 2001 to 2021. This time span also provides a comprehensive window to observe trends in the entire region during the LRT construction process and infer the impact of the LRT on the region. In the census program, the Region of Waterloo is represented as Kitchener-Cambridge-Waterloo Census Metropolitan Area (KCW-CMA). The KCW-CMA has a slightly different boundary from the Region of Waterloo. The Kitchener-Cambridge-Waterloo CMA only includes three major cities in the Region. Some townships were not included. This research focuses on the transit corridor and city cores; therefore, KMC-CMA definition best fits the research purposes.

For population data, national census data already provides a wide range of demographic information for the entire region. Additionally, the database contains population data corresponding to each census

tract, which can be used to compare population trends between the entire city and the LRT corridor area. However, for economic data, national census data can only offer employment and per capita/household income figures at the city-wide level. To delve into economic conditions within smaller regional areas, this study heavily relies on the analysis and conclusions from existing research. In contrast to the City of Buffalo, the Region of Waterloo presents an advantage due to the relatively recent timeframe covered by data. This research can gather data on land development applications in the City of Waterloo and Kitchener over the past 20 years from the Region of Waterloo Open data platform. This data can be used to uncover information about land development and utilization projects throughout the entire city and within the LRT corridor, allowing for insights into the impact of the LRT on land use.

From the transportation perspective, the travel behavior data is collected through the census program. LRT's ridership data are provided by the Grand River Transit. In addition, the Covid-19 pandemic greatly affected the operation of the LRT during the 2020 and 2021. To better understand the impact of the pandemic and try to exclude it from this research. A comparison between a couple of transit network in southern Ontario cities were made. Ridership data was collected through Canadian Urban Transit Association.

3.4.3 Data Analysis Process

In this research, there are different data sources for different types of data and the purpose is to have a comprehensive review on the urban development trend before and after the completion of the LRT project and to show the importance of the initial urban growth trend to the LRT's performance. As the data was collected from different data sources, it is unavoidable that there are minor changes in classification between census programs. Therefore, the collected data will be reviewed and modified before any analysis to ensure that all data follows a constant standard. This process is called Data Preparation Process and will be applied to all collected data in this research.

3.4.3.1 Demographic Data

Demographic Data is used to describe the population features for the selected case study in this research. Demographic data could show population characteristics like number of populations, age, sex,

and household information (Michaela & Frans, 2015). In this research, the demographic analysis is separated into two parts including both City-Wide demographic analysis and Transit Corridor demographic analysis. From a city-wide perspective, the demographic data are used to generate a general population change trend for the case study city. Within this study, population research primarily focuses on three aspects: population size, age structure, and population density. By comparing population data before and after the construction of the light rail system, this study achieves two objectives. Firstly, it can verify the accuracy of the initial background understanding in the feasibility study. Secondly, changes in population size, structure, and density before and after the project can indirectly reflect the impacts of the light rail system for the whole city. From the Transit-Corridor perspective, the demographic analysis could more directly show the impact of LRT on re-distributing population. The Transit-Corridor demographic analysis is based on the dissemination areas and census tracts. The census tracts that are mentioned in the EIA reports were reviewed (Aecom, Hatch Mott MacDonald, Region of Waterloo, 2009) (U.S. Department of Transportation Urban Mass Transportation Administration, 1977). According to the EIA report, there can be expected a higher population density and number of populations increase in those census tracts than the other parts of the city after the completion of the LRT. This research will track the population and density change for those tracts and city-wide. The trend leading up to the introduction of LRT and after the introduction of the LRT project will be compared to show the changes on the trends. During the long-time frame, some census tracts have disappeared or changed their boundary. In this study, for both case study cities, all original census tracts located within 500 meters of the light rail alignment were selected as the LRT corridor (all dissemination area that overlap with 500-meter buffer zones, even if it is partly overlap). Therefore, in this research, census tracts that are within 500 meters are considered as the Transit-Corridor related tracts for every census even those tracts may have different names or boundary. The LRT corridor area in both case study cities is shown in the figures below.

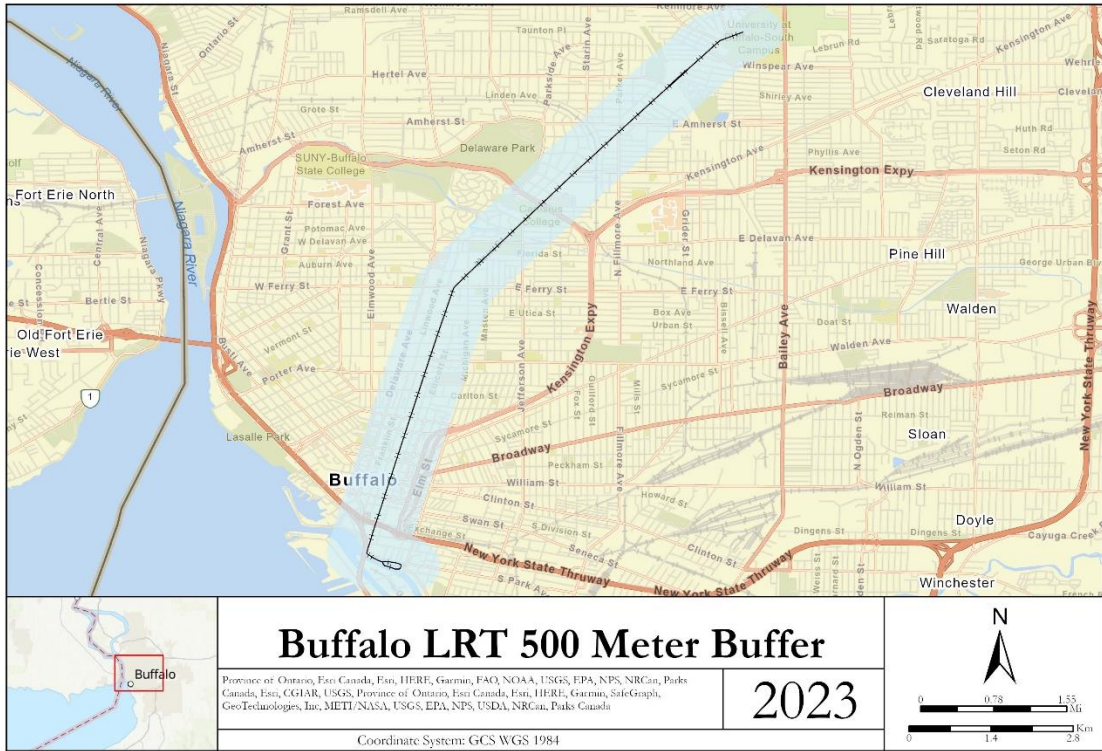


Figure 3-5 Region of Waterloo LRT 500 Meter Buffer

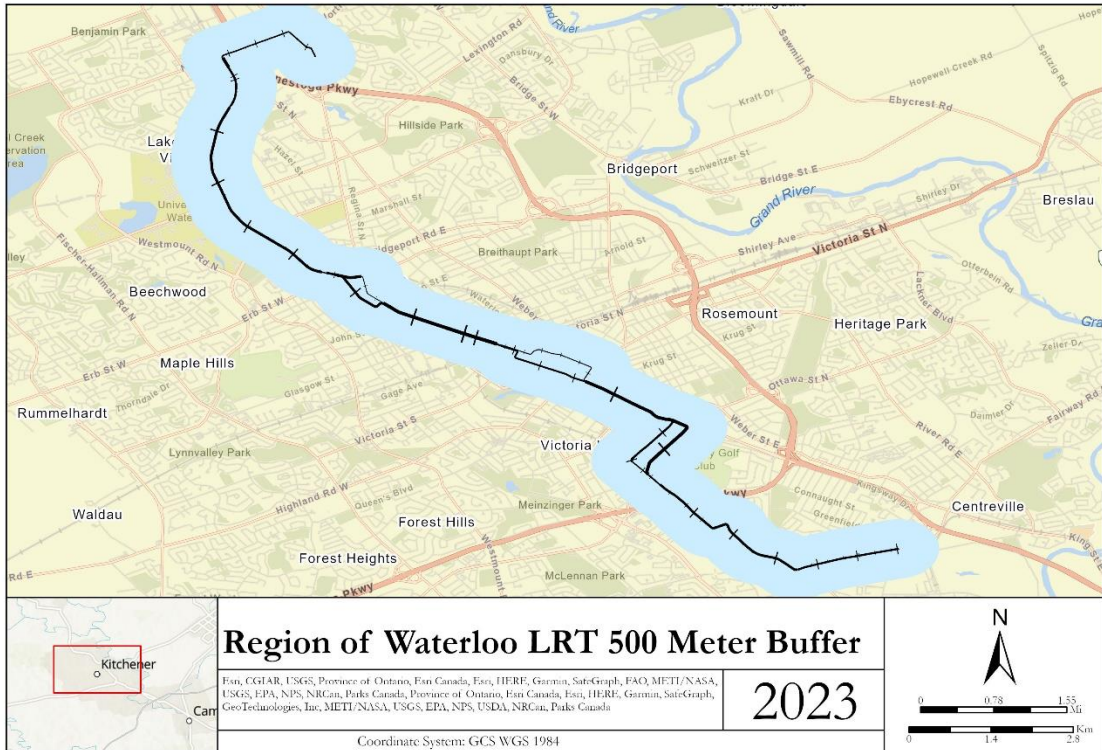


Figure 3-6 City of Buffalo LRT 500 Meter Buffer

3.4.3.2 Economic Related Data

As mentioned, employment data is one of the priority data to represent the economic development in the case study cities. The Employment data are typically used to represent employment occupation and economic development from an employment perspective (U.S. Census Bureau, 2022). For the Region of Waterloo, the employment status in each occupation category. Employment data include the change of number of employments within 9 major occupation types from 2011-2021 census (Statistic Canada, 2022). The occupation types include:

- Legislative and senior management occupations

- Business, finance, and administration occupations
- Natural and applied sciences and related occupations
- Health occupations
- Occupation in education, law and social, community and government services
- Occupations in art, culture, recreation, and sport
- Sales and service occupations
- Trades, transport and equipment operators and related occupations
- Natural resources, agriculture, and related production occupation
- Occupations in manufacturing and utilities

Despite slight variations in the definitions of employment categories between the City of Buffalo and the Region of Waterloo, a comparative analysis of the total employment opportunities and the categorization of various industries before and after the LRT's construction can still demonstrate the stimulating role of the LRT in economic development. For both case study city, due to limitation of data availability, there are only employment occupation for the city-wide level. Therefore, there is no direct data to compare the business activity between Transit-Corridor and the city-wide. However, Credit's (2018) study in Phoenix shows that within 1-mile range of the transit station. It is more likely to have increasing business services in knowledge, retail, and services sector. In addition, many other studies also prove that the introduction of the LRT could have a strong capability to redistribute the economic activities and development (Giuliano & Agarwal, 2004). These two findings perfectly matched the planning objective estimated in the EIA report (Aecom, Hatch Mott MacDonald, Region of Waterloo, 2009) (U.S. Department of Transportation Urban Mass Transportation Administration). Therefore, even though there is only city-wide employment data available, the employment data is expected to show a greatly increase of third industry especially in the transit corridors. Meanwhile, in this research, some indirect evidence like government documents and reports will also be used to evaluate the economic activities within the Transit Corridor. This research will compare the situation before and after the introduction of LRT to show the changes on the economic trends.

Personal and Household income generally refers to the gross income of one or all household members. The data could count all types of income from a person or a family. The income level is a valuable indicator to represent the standard of living of an area (Rati, 1985). In this research, both cities were facing a recession downtown area and hope to revert to recession by introducing LRT pass through. The income level could be a great indicator to show people's living standards and poverty issue. In this research, for both case study cities, the income level data are collected based on the city level. The income data were collected for before and after the introduction of the LRT to show the trend changes on people's living standards. For both cities, local income level will also be compared with the provincial and national levels to determine whether the development of the selected cities is leading or falling behind the provincial or national level.

In summary, this research will obtain the employment and household income data for both case study cities for both period before and after the completion of the LRT projects. For the employment data, it will not only include the total number of employment but also the distribution of labor force into each occupation types. The employment data will be used to track the change of the employment market in both case study cities and the distribution of labor force are used to track the change of cities' industrial structure. For the household income data, this research will obtain the household income level for both case study cities and state/provincial income level. In this research, the provincial/state and national household income will be considered as an example. The income level for both case study cities will be compared with state/provincial level to show the living standard in both case study cities.

3.4.3.3 Land Development

As mentioned in previous sections, the land development data is also used in this research to measure the impact of LRT projects in both case study cities. Land development trend is a great evaluation factor that has close connection with population distribution and economic development.

For the City of Buffalo, the LRT project was completed in 1984. Unlike the present day, back then, government departments did not have an online open data platform to provide relevant data regarding

land development permits. Even though the City of Buffalo now has an open data platform for sharing data, information on land development permits is still not publicly available. Consequently, there is no direct data available to illustrate changes in land development before and after the construction of the LRT. In this study, changes in land use are primarily analyzed through evidence from past studies, which serve as a basis for assessing the trends in land use before and after the LRT construction.

In this research, for the Region of Waterloo, the land development data will be collected through the Region of Waterloo Open Data database. In that database, all approved land development application in the City of Kitchener and City of Waterloo were collected (2023). In this study, land development data will be classified based on location into two groups: those located along transit corridors and those outside transit corridors. Transit corridors refer to the coverage area within 500 meters along the light rail line as mentioned previously. For both groups of data, the land development permit will be categorized into different groups based on the property types. This study focuses on the development of mixed-use land development and multi-unit residential buildings, which can quickly bring changes to the urban landscape and serve as a target land development mode mentioned in the EIA report (Aecom, Hatch Mott MacDonald, Region of Waterloo, 2009). Typically, mixed-use land development and high-density communities are also the ideal land development type for the Transit-oriented Development. Similar to other types of data, two kinds of comparison will be made for the land development data. First comparison is about the land development situation before and after the completion of the LRT project which could show the trend of land development. The other one is to compare the land development within and outside the transit corridor which shows the distribution of target types of land development. By comparing the land development types along transit corridors with those in other parts of the city, this study can also indirectly demonstrate the impact of light rail projects on the urban landscape.

3.4.3.4 Transportation Data

As mentioned in the previous sections, the research's analysis on the transportation data will focus on two major parts including the LRT's ridership and people's travel behaviour. The ridership data

analysis is a direct method to show how many people use the Light Rail system. For both case study cities, the ridership data will be compared with the ridership expectation in the EIA report to evaluate the people's acceptance of the LRT system. In addition, the ridership level will also be used to estimate the fare-recovery ratio which can also show the revenue generation capacity and financial status of the project.

Differences in the circumstances of the two case study cities have necessitated distinct approaches to collecting and analyzing ridership data for this research. These disparities in context have led to variations in data availability and data collection methods. As a result, this study has employed unique strategies tailored to the specific characteristics and data sources of each city. For the City of Buffalo, the LRT's ridership data is collected annually. However, the situation is somewhat complex for the Region of Waterloo. The Region's light rail project commenced operations in July 2019, and since March 2020, the COVID-19 pandemic has had a significant impact on LRT operations. The widespread lockdown measures severely disrupted people's normal travel patterns and modes of transportation. As a result, this research employed specific methodologies to mitigate the influence of COVID-19 on the data analysis. Due to the availability of monthly ridership data in the Region of Waterloo and the eight-month period between the opening of the LRT and the onset of the pandemic, this study extrapolated the ridership for the first year of LRT operations by calculating the average monthly ridership over these initial eight months. The project annual ridership data can build up part of the ridership trend for the LRT project. However, unaffected ridership data for a longer period will also be needed to reveal the real ridership level for the LRT project. To better understand the impact and duration of the pandemic to the public transit system, this research will do a comparative analysis between multiple mid-size cities (Brampton, London, Kingston, Mississauga, and York Region) in southern Ontario. For these cities and Region of Waterloo, monthly ridership from 2019 to 2021 were collected. The 2019 ridership will be considered as baseline and help to determine the ridership recovery from pandemic. Monthly ridership data from March 2020 will be projected to a annual basis and compared to the 2019 level. Based on the result of the pandemic impact assessment, this research could pick up a good time point when the ridership data could re-represent the people's real demand and acceptance for the LRT project.

Simultaneously, the study places a significant emphasis on understanding how LRT systems influence people's travel patterns and modes of transportation. Within census products, there are statistics available regarding commuting modes of the working population, which serve as a crucial data source for this aspect of the research. For both cities, the commuting mode data before and after the introduction of the LRT will be compared to generate the trend of change on people's travel behaviour. Meanwhile, as mentioned in the EIA report, non-working population like the older population, student and people without jobs are also target customers for the LRT project. The commute data did not take them into account. To better understand how the LRT project serves them, this research will find indirect evidence like government report and exist research.

Chapter 4 Research Outcome

4.1 Chapter Outline

Chapter 3 presented the research methods, introduced the case study cities, and described the data collection and analysis process. This chapter follows the structure built by the previous chapter and presents the data collected from a variety of data sources. These data cover demographic, economic, land development and transportation aspects of both case study cities. In addition, this chapter will also show the comparison between forecasted situation described in the Environmental Assessment reports with the reality. The comparison between predicted data and real-world outcomes serves two essential purposes within the context of this study. Firstly, it allows for the comprehensive assessment of the LRT project's performance across various aspects. Secondly, this comparison also sheds light on the accuracy of the forecasting and planning processes that preceded the LRT implementation.

This chapter is designed to accomplish several key objectives. It will unveil the outcomes of demographic data analyses conducted on both case study cities, offering insights into population dynamics. Additionally, it will present findings from economic data analyses, shedding light on employment rates, income distributions, and other economic factors in the respective cities. The chapter will delve into transportation data analyses, outlining patterns and trends in ridership and mode shares. By interpreting and comparing these data-driven insights with the earlier established planning objectives, the chapter aims to provide a comprehensive evaluation of the LRT project's performance in both case study cities, ultimately culminating in informed conclusions.

4.2 City of Buffalo

4.2.1 Result for Demographic Data Analysis

As mentioned in Turner's (1991) previous research for the City of Buffalo, for two decades before the LRT in the City of Buffalo was introduced, from 1950 to 1969, the city experienced a population

decline of -8.20%. The population loss ratio per decade even raised to -13.14% between 1960 and 1970 (U.S. Census Bureau, 1960; U.S. Census Bureau, 1970). The LRT project was completed in 1984 and the Census Program in United States was decennial, therefore the collected demographic data covers between 1960 to 2000. The population change from 2000 to 2020 would not be included in this section.

According to the EIA report for Buffalo’s LRT project (1977), several third-party agencies had performed a population projection for both Buffalo Metropolitan Area and City of Buffalo. The result showed that, from 1975 to 1995, there would be an average 0.5% to 1% annual population increase in the Buffalo Metropolitan Area. However, for the City of Buffalo, the third-party agencies estimated that there would be an average 0.6% annual population decrease from 1975 to 1995. According to the EIA report (1977), the population increase within the Buffalo Metropolitan area would have occurred in Amherst and Tonawanda (Two Suburb near City of Buffalo). The LRT project was planned to increase the accessibility to the Central Business District and stimulated the development in the city core.

	1975	1980	1985	1990	1995
Cornell Aeronautical Lab	460,000		451,000	469,000	
Larry Smith & Company	453,876		436,610	428,225	420,000
NFTC	433,302		400,000		
NYS Economic Development Board	426,000	393,000	371,000	349,000	339,000
Economic Consultants Organization, INC	433,302		395,266	382,012	371,721
ENCRPB	433,302	412100	395,226-419,981	382,012	371,721

Table 4-1.1 City of Buffalo Population Forecast (Final Environmental Impact Statement Buffalo Light Rail Rapid Transit, 1977, p. 25) (Population Data for 1975 is actual data and rest of data were projected)

However, the real-world situation was greatly different from what was projected in the EIA report. Based on the census data from U.S. Census (U.S. Census Bureau 1970-2000), unlike the projection,

the Buffalo-Niagara MSA did not have an increase population. Instead, its population dropped from 1.34 million to 1.17 million with a 0.4% annual population decrease. The situation was even worse for the City of Buffalo. From 1970 to 2000, the City of Buffalo lost 37% of its population which represented a 1.23% annual decrease ratio. The population drop in the City of Buffalo doubled the estimation (U.S. Census Bureau, 1970; U.S. Census Bureau , 1980; U.S. Census Bureau , 1990; U.S. Census Bureau, 2000). In the two suburb areas, Amherst did have an increasing population from 1980 to 2000 with 0.4 % annual increase rate. But the increase ratio was 50% lower than expected. Tonawanda suffered from a decreasing population with a 0.7% annual decrease rate which was totally contradicted to what was expected (U.S. Census Bureau , 1980; U.S. Census Bureau , 1990; U.S. Census Bureau, 2000).

	Buffalo-Niagara MSA	City of Buffalo	Amherst	Tonawanda
1970	1,349,211	462,768		
1980	1,242,826	357,900	108,706	91,269
1990	1,189,340	328,100	111,711	82,464
2000	1,170,111	292,600	116,510	78,115
Annual Change Ratio	-0.44%	-1.23%	0.36%	-0.72%

Figure 4-1 Population Change (Buffalo MSA, City of Buffalo, Amherst, Tonawanda) 1980-2000 (U.S. Census Bureau 1980-2000)

In the Environmental Impact Assessment (EIA) report, it was noted that by the year 1980, the proportion of the population aged 60 and above would increase from 18% (1970 level) to 22% and the proportion of the population aged 18 and below would drop from 31% (1970 level) to 28%. (U.S. Department of Transportation Urban Mass Transportation Administration, 1977). In general, the dependent group (population over 60 and below 18) would increase 1 % of its share of total

population in 1980s. In the EIA report, the women and the dependent groups were considered as the most possible potential customer for LRT project. And the portion of these groups were expected to increase (U.S. Department of Transportation Urban Mass Transportation Administration, 1977).

In the real world, after the completion of the LRT project, the census data shows that from 1980 to 2000, the dependent group increased 2 % of its share of total population in the City of Buffalo. However, if considering the decrease on the total population, the scale of dependent group shrinks by 20,000 people which was a 13% decrease (U.S. Census Bureau , 1980; U.S. Census Bureau , 1990; U.S. Census Bureau, 2000).

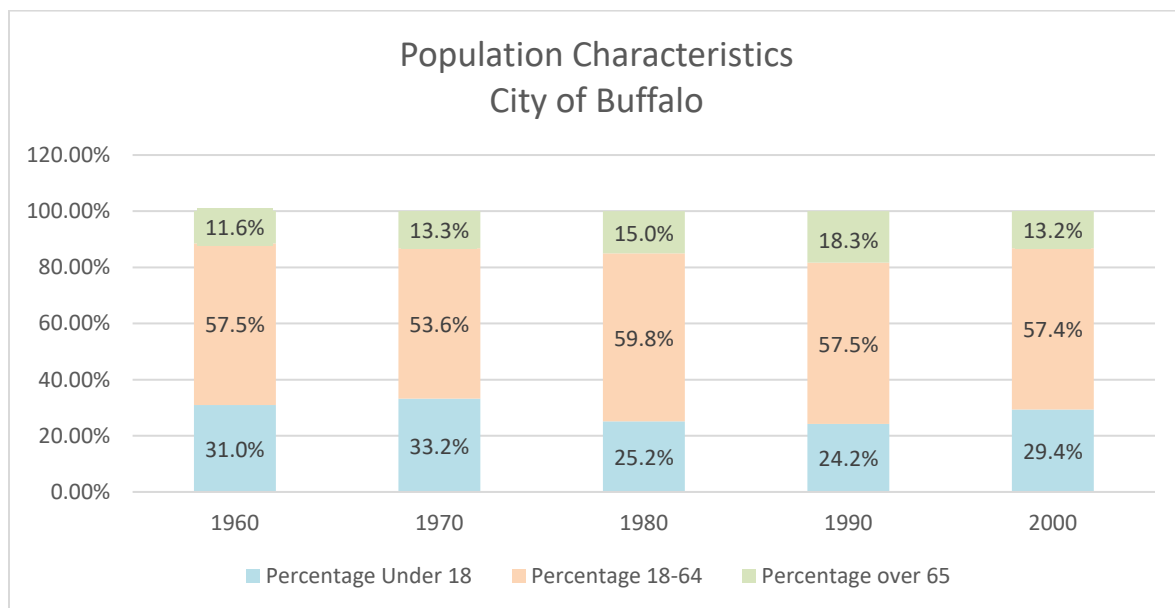


Figure 4-2 Age Distribution City of Buffalo (U.S. Census Bureau 1960-2000)

In addition, the population change in the City of Buffalo is also connected to a larger scale of Regional Development Trends. Suburbanization is one of the most well-known phenomena which refer to the trend of people moving from city-cores to suburbs (Mieszkowski & Mills, 1997). The City of Buffalo also encountered Suburbanization before the LRT was built. From 1960 to 1970, even though the population of City of Buffalo was decreasing, the population of Buffalo MSA was

growing (U.S. Census Bureau, 1960; U.S. Census Bureau, 1970), which represent a growing suburban area around City of Buffalo. In the EIA report, the suburbanization process was clearly identified. The report recognized that growing population in suburbs and losing population in the city core. In addition, in the population project, the result also showed that most population increase would be more likely to happen within the suburbs. The city core would be more likely to keep losing its population (U.S. Department of Transportation Urban Mass Transportation Administration, 1977).

Another regional development trend gained popularity when the LRT was under construction was “Rust Belt”. Rust Belt describe the region that experience industrial prosperity in the nineteenth and first half of twentieth centuries and decayed in the second half of twentieth century (Duryea, 2015, p. 15). The City of Buffalo, due to its scale and economic features, is a representative city within the Rust Belt Region. On the first half of the twentieth century, Buffalo was famous for its steels and manufacturing industry due to the advantage on raw material and electricity (Goldman, 2007). However, after the artificial high demand during two world wars, the decline became evident in 1960s (Duryea, 2015). The employment loss started from the Steel industry and then expanded to the whole manufacturing industry. From 1970 to 1980, Buffalo lost nearly 40.6% jobs in the manufacturing industries (Goldman, 2007). Compared to other cities within the Rust Belt, the City of Buffalo was one of the most significantly affected cities. According to the Poon and Yin’s (2014) research for 21 Rust Belt Cities, Buffalo- Niagara MSA had the biggest population loss between 1980 – 2010 which ranked highest for all large cities within the rust belt. In the EIA report for the City of Buffalo, the researcher clearly noticed the downward population tractor within the city boundary and potential population increase might occurred in the suburbs (U.S. Department of Transportation Urban Mass Transportation Administration, 1977, pp. 2-22). However, in the EIA report, the downward population trajectory for city center did not became a significant concern for the LRT project.

In some cases, the number of populations may easily be affected by the immigration or migration, another important number that could represent the population change is the number of households (Gaube & Remesch, 2013). Moreover, characters like number, composition, size of the household could also directly link to the demand of residential units and affect the urban development (Coulombel, 2010). According to the census data from 1960 and 1970 (U.S. Census Bureau, 1960;

U.S. Census Bureau, 1970), before the LRT was completed, the City of Buffalo had a decreasing trend of total number of Household and Population per Household. In the EIA report (1977), the change on household were not projected. Based on the census data, corresponding to the decreasing population, the number of households and household size continued to decline from 1980 to 2000 (U.S. Census Bureau , 1980; U.S. Census Bureau , 1990; U.S. Census Bureau, 2000). During the three decades, the City of Buffalo loss around 18000 families with a 0.4% annual loss ratio (U.S. Census Bureau , 1980; U.S. Census Bureau , 1990; U.S. Census Bureau, 2000). The decreasing number of households and shrink household size also represent a shrinking demand for the residential unit within the city boundary.

Compared with other parts of the city, areas near the LRT line are more likely to benefit from agglomeration effect. As mentioned in the Chapter 3, the agglomeration effect for a LRT project was usually quantified through the population density change in the Census Tracts near the LRT lines. In the EIA report (1977), the researcher predicted that there would be a moderate increase on the population density along the LRT project. In the report, 25 census tracts were selected as the transit corridor area for the LRT project. However, in the EIA report, the researchers indicated that the population density for City of Buffalo was around 4300 people per square kilometer before the construction of the LRT project (U.S. Department of Transportation Urban Mass Transportation Administration, 1977).

	1970 Density	1980 Density	1990 Density	2000 Density	Change 1970- 2000
City of Buffalo	4859	3453	3048	2868	-40.98%
Transit Corridor	5039	3870	3536	3162	-37.26%
Ellicott & Masten	5156	3459	3031	2812	-45.45%

Table 4-2 City of Buffalo Population Density Change 1970-2000 (Integrated Public Use Microdata Series (IPUMS), 2022)

According to the census data, the population density change in City of Buffalo and Transit Corridor was quite different from what was estimated in the EIA report. In the Figure 4-3, each block

represented as a census tract within the City of Buffalo's boundary. The blue buffer zone shows the location of LRT corridor and census tracts overlay with the blue buffer are selected census tracts. The color of the census track represents the change of population density from 1970 to 2000. From a city-wide perspective, the population density stood at 4,859 individuals per square kilometer, and by 2000, it had dropped to 2,868 individuals per square kilometer, representing a substantial decrease of 40.98% (Integrated Public Use Microdata Series (IPUMS), 2022). From the transit corridor perspective, the population density within the 25 selected census tracts underwent significant decline from 1970 to 2000.

From the census tract data, the population density within the Transit Corridor was 5,039 individuals per square kilometer, declining to 3,162 individuals per square kilometer by 2000, marking an average reduction of 37.26% (Integrated Public Use Microdata Series (IPUMS), 2022). Notably, within the Transit Corridor, specific regions such as Ellicott and Masten experienced more pronounced declines, with a population density decrease of 45.45%, surpassing both the Transit Corridor and citywide averages. Ellicott and Masten are two areas closest to the Buffalo's CBD and located on the west side of the LRT Corridor. As they are closest the city core, these two areas are more vulnerable to population migration to the suburbs. And that explains why these two areas encountered greatest population density decrease.

When considering the population density changes from 1980 to 2000, which coincided with a 45% population loss in the city, it becomes apparent that the alterations in population density align with the expected patterns of demographic change. This observed decline in population density corresponds with the significant population losses over the same period. In addition, as the population density change between transit-corridor and other part of the city were close, the LRT project in Buffalo did not show its agglomeration effect for transit corridor. The LRT project failed to reverse the decreasing trend on either total number of population or the population density. The continuing decreasing trajectory has proved that wrong estimations has been made in the EIA reports.

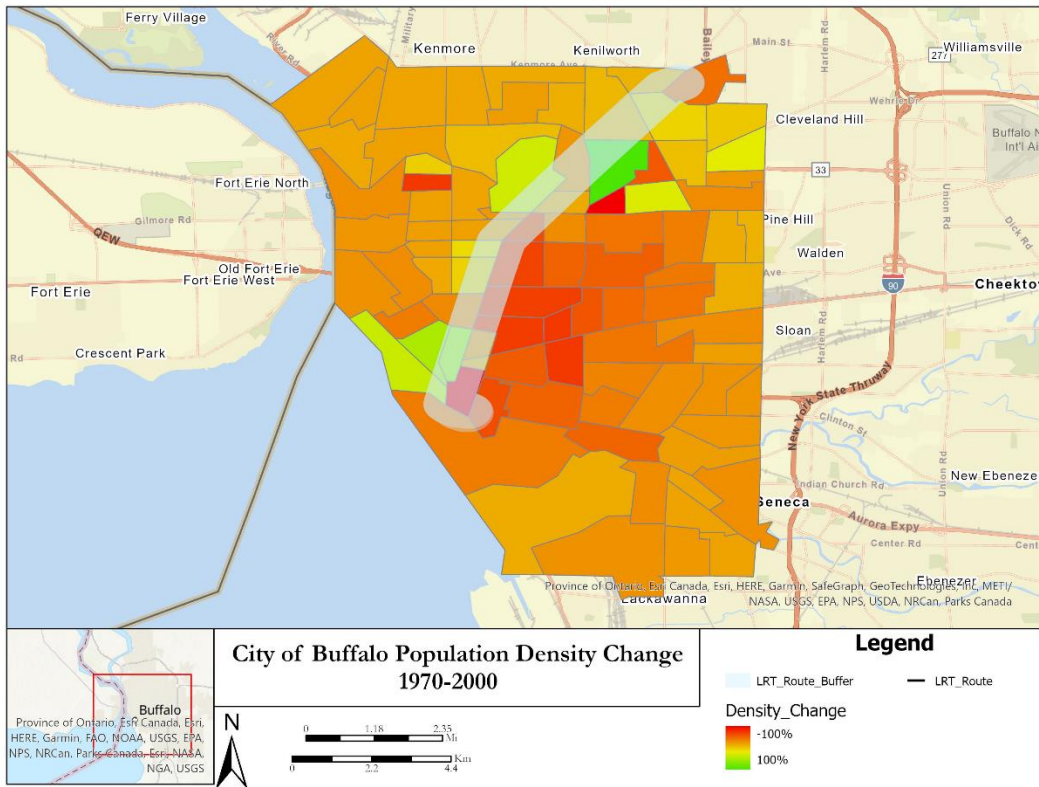


Figure 4-3 City of Buffalo Population Density Change 1970-2000 (LRT Corridor shown as Blue Buffer, each block is a Census Tract)

4.2.2 Result for Economic Data Analysis

According to the EIA report, the employment opportunities in Buffalo Metropolitan area was projected to have a 2550 to 2800 annually increase from 1980 to 1995 and half of the employment opportunity increase would occur in the City of Buffalo (Final Environmental Impact Statement Buffalo Light Rail Rapid Transit, 1977). A variety of employment forecast in the EIA report all mentioned that the employment opportunity increase would come from third industries like government, business, finance, personal service, retail, real estate, insurance, transportation, communication, and utilities (Final Environmental Impact Statement Buffalo Light Rail Rapid Transit, 1977). The projections also stated that even though the availability of labour force would be decrease in the City of Buffalo, half

of the new employment opportunities will still occur in the city and people will commute from suburban area to the city center to work (Final Environmental Impact Statement Buffalo Light Rail Rapid Transit, 1977).

In contrast, the actual employment data paints a different picture over the period from 1980 to 2000. The City of Buffalo saw a significant decline in employment, with a 12% reduction, while the broader Metropolitan area of Buffalo experienced an even more substantial drop of 34 (U.S. Census Bureau , 1980; U.S. Census Bureau , 1990; U.S. Census Bureau, 2000). Despite variations in employment categories between the 1980, 1990, and 2000 censuses, the data consistently reveals discernible trends in many industries shown as Table 6. Notably, the wholesale and retail trade sectors suffered considerable setbacks, with a contraction of approximately 13% and 43%, (U.S. Census Bureau , 1980; U.S. Census Bureau , 1990; U.S. Census Bureau, 2000). In addition, researcher noticed that since 1979 CBD was no longer the most attractive retail center in the Buffalo Metropolitan Area (Department of Environmental Design and Planning, State University of New York at Buffalo, 1981). The suburb shopping malls became more attractive to people living in both suburbs and city core (Department of Environmental Design and Planning, State University of New York at Buffalo, 1981). Additionally, public administration employment declined by 16%. The transportation, finance, and real estate sectors all grappled with economic downturns during the two-decade period from 1980 to 2000 (U.S. Census Bureau , 1980; U.S. Census Bureau , 1990; U.S. Census Bureau, 2000).

	1980		1990		2000			Change %
Transportation Communication, Public Duties	9,106	6.93%	8350	6.37%	Transportation and warehousing, and utilities	6223	5.50%	
Wholesale Trade	4,903	3.73%	4891	3.73%	Wholesale trade	4257	3.70%	-13%
Retail Trade	21,214	16.15%	22415	17.11%	Retail trade	12172	10.70%	-43%
Finance Instructure and Real Estate	6,953	5.29%	9282	7.09%	Finance, insurance, real estate, and rental and leasing	6509	5.70%	-6%
Business and Repair Service	4,845	3.69%	5933	4.53%	Educational, health and social services	32384	28.40%	
Personal Service	3,732	2.84%	3864	2.95%	Professional, scientific, management, administrative, and waste management services	9774	8.60%	
Entertainment and Recreational Service	1,307	1.00%	1461	1.12%	Arts, entertainment, recreation, accommodation and food services	9487	8.30%	
Professional And Related Service	33,697	25.66%	41097	31.37%	Other services (except public administration)	5498	4.80%	
Public Administration	7,195	5.48%	6901	5.27%	Public administration	6012	5.30%	-16%

Table 4-3 Number of Employment in Third Industry Buffalo Metropolitan Area

However, besides the underperformance of the tertiary sector, the decline of the industrial sector also constitutes a significant factor contributing to the bleak employment prospects as expected in the previous sections. As the epicenter of the Rust Belt region, the City of Buffalo's industrial workforce has endured a substantial downturn. In 1950, over half of the labor force was employed in industrial-related jobs (Manning, 2015), but by 1980, this proportion had dwindled to 25% (U.S. Census Bureau

, 1980), and by 2000, it plummeted further to just 13% (U.S. Census Bureau, 2000). This decline in industrial employment has had profound implications for the city's economic landscape and employment opportunities.

From the household income perspective, the household income rose from \$6,465 to \$24,536 from 1960 to 2000. However, due to inflation over the decades, the net worth of the income in 1960 is even more valuable than 2000's level. On the contrary, in New York State, the median household income was \$31,591 in 1990 and \$40,744 in 2000. Moreover, the national median household income rose to \$29,943 in 1990 and \$41,990 in 2000 (U.S. Census Bureau, 2000). Buffalo's income level gradually fell behind the average level compared to state and national standards. In 2000, the median household income in Buffalo was only 60.2% of the median income level for the state of New York and 58.2% of the national average. The decline in income levels is also evident at the individual income level. In 1960, the Buffalo metropolitan area's income level ranked 79th out of 352 metropolitan areas in the United States. However, by 1980, this ranking had dropped to 115th place, and by 2000, it further declined to 119th place.

The result of employment and household income shows to implication about the LRT's performance. Firstly, the LRT did not stop the recession trajectory as proposed in the feasibility study. The employment market and household income level were shrinking in the twenty years after the completion of the LRT project. In addition, the distribution of occupation, shows that the completion of the LRT did not show a strong stimulation effect on the retail industry. Meanwhile, the shrinking employment also support and explain the decrease of the city's population and travel demand which lead to a unexpected low ridership.

4.2.3 Result for Transportation Data Analysis

During the planning stage, it was estimated that the ridership for LRT project would be 20 million annually and gradually increased over 30 million in 1990s (Depart of Environmental Design and Planning, State University of New York at Buffalo, 1981). When the system was first opened in the mid-1980s, the records show the annual ridership of the LRT was 8 million. However, the ridership

has gradually decreased since then. Research from 1989 which was 5 years after the LRT completion had notified that the ridership was greatly over estimated. The research compared the ridership level from 1988 to the estimated ridership and noticed that there was a 68% overestimate on the weekday boarding numbers (Transportation System Center U.S. Department of Transportation, 1989). In 2000, the Light Rail Transit in Buffalo had an annual ridership of about 6.5 million, with 18,000 passengers per day (United States Department of Transportation Federal Transit Administration, 2020). The loss on ridership was way faster than the population change. Until 2019, the ridership decreased to 4.5 million yearly, with only 12,000 passengers per day (United States Department of Transportation Federal Transit Administration, 2020). The ridership was only 10% of its estimation in the 1970s. The low ridership also represented a poor performance on the fare recovery ratio. The low ridership resulted to more government operating assistance was needed to support the operation of the Buffalo Light Rail Project.

According to the LRT's Environmental Impact Statement (1977), in 1970, 64% of the working population relied on public transit, which highlights the potential impact of the LRT on travel behavior. In the EIA, it was estimated that the completion of the LRT could reduce the usage of automobile in Buffalo and lead to improvement on the traffic and air quality (Final Environmental Impact Statement Buffalo Light Rail Rapid Transit, 1977).

	Private auto, driver	Private auto, passenger	Public transit	Walked only	Other means	Worked at home
1970	42.65%	12.52%	24.39%	14.81%	0.54%	5.09%
1980	39.98%	12.99%	22.27%	22.25%	0.91%	1.60%
1990	52.16%	8.01%	19.16%	16.98%	0.81%	2.67%
2000	69.54%		20.11%	6.45%	0.94%	2.57%

Table 4-4 Mode of Commute LRT neighboring Census Tract (U.S Census Data, 1970-2000)

	Private auto, driver	Private auto, passenger	Public transit	Walked only	Other means	Worked at home
1970	63.86%	11.91%	11.65%	8.48%	1.25%	2.86%
1980	61.44%	18.35%	9.13%	8.66%	0.92%	1.50%
1990	72.01%	11.67%	6.94%	6.32%	0.55%	1.99%

2000	82.61%		5.30%	4.15%	0.42%	1.94%
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Table 4-5 Mode of Commute Erie County (U.S. Census Data, 1970-2000)

The empirical evidence reflects the enduring prominence of private automobiles from 1970 to 2000. Analyzing the Integrated Public Use Microdata Series (IPUMS) census data in the census tracts affiliated with the Light Rail Transit (LRT) project, it becomes evident that the proportion of individuals driving private vehicles surged dramatically, escalating from 42.65% to 69.54% over the three-decade (Integrated Public Use Microdata Series (IPUMS), 2022). Unlike what was expected in the feasibility study, after the completion of the LRT, there wasn't an obvious increase in the acceptance of the public transit. The result shows that the usage of public transit decreased from 22.27 % to 20.11% since the completion of the LRT in both City of Buffalo (Integrated Public Use Microdata Series (IPUMS), 2022). Considering the decreasing employed population, that's a huge loss on public transit demand. Expanding the perspective to the Erie County region, the census data confirms an increasing reliance on automobiles and a notable decrease in the use of public transportation. Compared with the regional-wide data, the LRT-related area has a slightly lower decrease on public transit usage, but the difference was not obvious. In addition, from the travel time perspective, the average commute time for LRT related area was quite stable from 1980-2000. At the same time, the average commute time for the Erie County increased by 6%. The travel time data reveals that the completion of the LRT project did not have a huge improvement on the accessibility within in the city.

Consequently, the comprehensive census analysis showed that the LRT project in the City of Buffalo did not meet its proposed ridership forecast. The low ridership also means the LRT project failed to gain enough revenue which was proposed in the feasibility studies. In addition, the result also showed that the completion of the LRT project did not greatly change the people's travel behavior in both the city and its suburbs. People preferred to drive to its work and the average travel time was increased. In general, the LRT project in Buffalo failed to meet all transit-related goals proposed in its feasibility study.

4.3 Region of Waterloo

4.3.1 Result for Demographic Analysis

According to the Region of Waterloo Regional Growth Management plan, as the fastest-growing urban areas in Canada, the Region of Waterloo's population has grown rapidly since 1970s and expected to have a population to 729,000 in 2031 (Region of Waterloo, 2003). Analyzing the census data, a consistent pattern of population growth throughout the period was observed, with varying growth rates from one five-year interval to another (Statistics Canada, 2021).

From 1981 to 2006, as shown in the Figure 4-4, the Region of Waterloo exhibited a consistent upward trajectory in its population, registering an average growth rate of 9.8% every five years (Statistics Canada, 2021). Notably, there were three distinct periods marked by accelerated population growth: 1986-1991, where the growth rate reached 25.93% (Statistics Canada, 1996); 2001-2006, with a growth rate of 10.1% (Statistics Canada, 2006); and 2016-2021, recording a growth rate of 10.21% (Statistics Canada, 2021). Simultaneously, from 2006 to 2021, the Region of Waterloo ascended from being the 10th most populous Metropolitan Area to the 4th most populous because of the increasing population (Statistics Canada, 2021). Drawing upon the population trends of the past four decades, the Region of Waterloo is projected to sustain its rapid population growth. Considering this trajectory, it is highly probable that by 2031, the region's population will not only meet but potentially exceed the anticipated figures as shown in Figure 4-4.

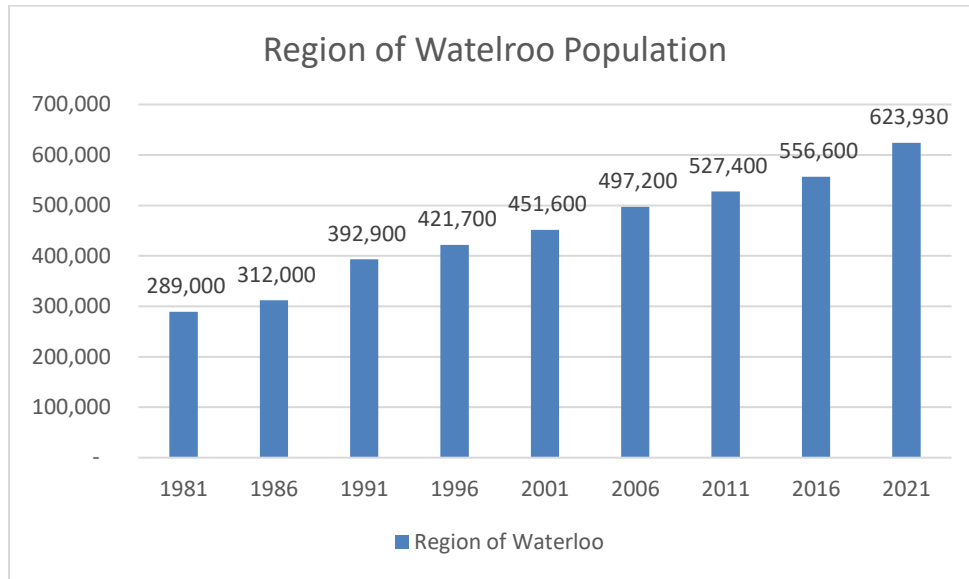


Figure 4-4 Region of Waterloo Population 1981-2021 (Statistic Canada, 1981-2021)

In the Regional Growth Management Plan and Environmental Assessment report for the LRT project, there are no detail projection of the age structure for the Region. However, in the EA report, it mentioned that the introduction of the Light Rail project aims at increasing the attractiveness people at a relatively younger age (Aecom, Hatch Mott MacDonald, Region of Waterloo, 2009). The age structure in the Region of Waterloo did not encounter huge changes over the years, as indicated from Figure 4-5.

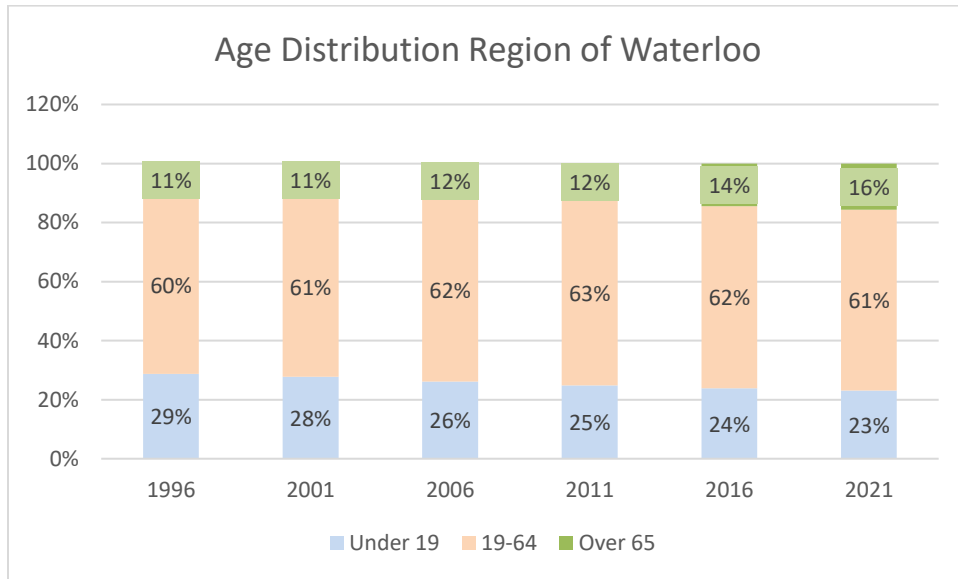


Figure 4-5 Age Distribution Region of Waterloo (Statistic Canada, 1996-2021)

However, the demographic shift in the Region of Waterloo has led to significant changes in the population distribution across age groups. Between 1996 and 2021, the population aged 0 to 14 years experienced a steady rise from 86,320 to 98,595, marking a 14% increase (Statistics Canada, 2021; Statistics Canada, 1996). In parallel, the age group of 15 to 64 years witnessed consistent growth, surging from 267,090 to 387,550, representing a 45% increase over the same period (Statistics Canada, 2021; Statistics Canada, 1996). Notably, the age group over 65 demonstrated the most rapid growth, escalating from 43,360 to 89,705—a remarkable 107% increase. Examining the median age, we can observe a gradual increase from 36.4 years in 2006 to 38.0 years in 2021. From the result, even though the Region of Waterloo is under an increasing population trajectory, there is a sign of population aging. Light Rail’s capability of attracting young age population is either not shown or non-effective.

In both Regional Growth Management Master Plan and EA report for Light Rail, they mentioned that one of the key functions of the Light Rail is to relocate the population and stimulate the high-density development within the Central Transit Corridor (Region of Waterloo, 2003; Aecom, Hatch Mott MacDonald, Region of Waterloo, 2009). The population density within the 29 census tracts located in the LRT transit corridor in the Region of Waterloo underwent noticeable changes between

2011 and 2021. As shown in Figure 4-6, there is a trend of increasing population density over the decade. From 2011 to 2021, the population density within these census tracts experienced a significant rise. The population density change ranged from 2128 persons per square kilometer in 2011 to 2935 persons per square kilometer in 2021. This represents a substantial increase of 43.54% in population density within the LRT transit corridor. It is also verified by the Monitor Change in the Central Transit Corridor Report. By the end of 2020, almost one-fifth of Region’s population lives in the CTC. From 2011 to 2019, one third of regional population growth were in the CTC and CTC had a doubled population growth ratio than other part of the region (Region of Waterloo, Planning, Development and Legislative Services, 2020).

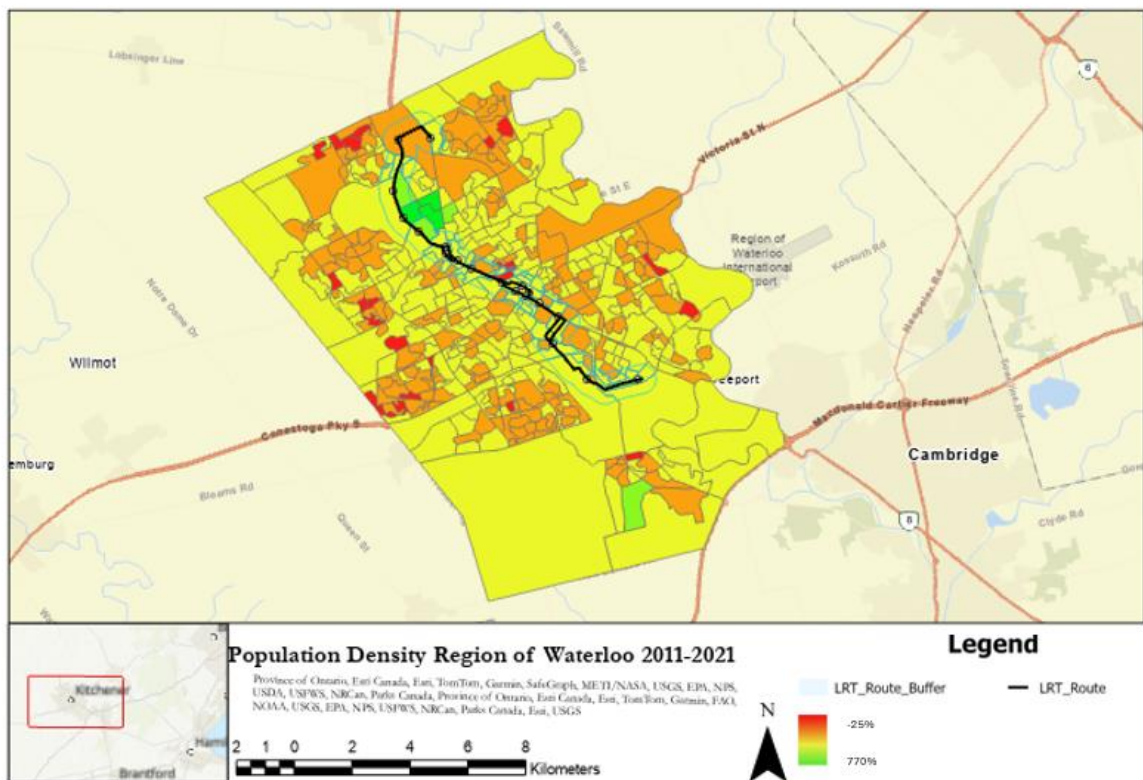


Figure 4-6 Population Density Change 2011-2021 Result for Land Development Analysis (Created by Author, Data Source: Statistic Canada)

From the urban development perspective, for the last decades, the Region of Waterloo has been moving towards a trend of densification, with a higher proportion of multiple-unit residential buildings constructed in the LRT corridor. Increasing density and reshape the community were also mentioned that in the Regional Growth Management Plan and EA report as one of the key goals for the LRT project (Region of Waterloo, 2003).

Based on the development permit data for the City of Kitchener (City of Kitchener, 2023) and City of Waterloo (City of Waterloo, 2023), in terms of overall residential development, the LRT corridor accounted for only for only 4.7% of all the residential development in both cities. However, these developments provided 19% of all new residential units in the city from 2011-2021, with a total of 5,960 new units (City of Kitchener, 2023; City of Waterloo, 2023). In contrast, the city as a whole saw 33,647 new residential units constructed over the same period. However, when it comes to multi-unit residential development, the picture looks quite different. In the LRT corridor, 96.4% of all new residential units were in multi-unit residential buildings, compared to 68% city-wide (City of Kitchener, 2023; City of Waterloo, 2023). There were 163 Multiple-Unit Residential building applications which contribute to 12,749 new units in the LRT-corridor. Breaking it down further, the most common type of multi-unit residential building in the LRT corridor was apartments and residential/commercial buildings. This was also the most common type of multi-unit building city-wide. However, the proportion of new units in apartments was much higher in the LRT corridor (45%) than in the city (32%). Based on the data from the City of Kitchener and City of Waterloo, it can be observed that there has been a shift towards multi-unit residential development in these cities, especially in the LRT corridor. This indicates a change in the urban form from predominantly single-family homes to a mix of multi-unit residential and transit friendly community along the LRT corridor. The increase in multi-unit residential development fits the objectives that mentioned in the Regional Growth Plan and EA for the LRT and can be seen as an effective solution in reacting to redistribution of increasing population and stimulate the downtown areas.

4.3.2 Region of Waterloo Economic Results

In the EIA report, it mentioned that the LRT project should stimulate the economic development city-wide by providing better transit access. The Central Transit Corridor should be the most beneficial

area which expected to become ideal destination for service and retail industry (Aecom, Hatch Mott MacDonald, Region of Waterloo, 2009).

According to the census result, corresponding to the increasing population, the scale of labour force and employment opportunities has increased by 23.04% from 1996 to 2016 (Statistics Canada, 2016; Statistics Canada., 2011; Statistics Canada, 2006; Statistics Canada, 1996). In addition, the employment occupation structure has dramatically changed over the last two decades as shown in Figure 8. The natural and Applied Science section and Education, Law and Social, Community and Government Services had doubled their scales. These employment positions all industrial sectors except Manufacturing and Wholesale increased by at least 30% during the last two decades (Statistics Canada, 2016; Statistics Canada., 2011; Statistics Canada, 2006; Statistics Canada, 1996).

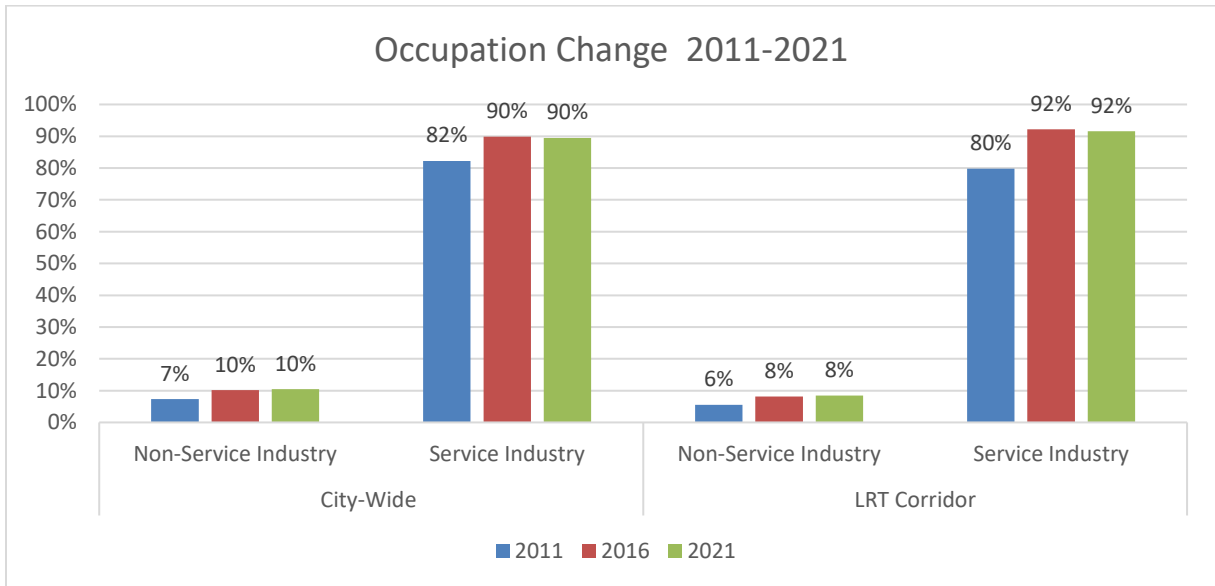


Figure 4-7 Region of Waterloo Occupation Change (Statistic Canada, 2011-2021)

As the employment data were collected based on the census tract, the employment data represents the employment occupation for people who live in each census tracts. So, the result in this research could not represent the actual location of the employment opportunity. The data shows the occupation change for the people who live in the LRT corridor or other part of the Region.

In terms of the non-service industry, the city-wide population exhibited a slight increase from 7.3% in 2011 to 10.5% in 2021, indicating a growth in employment opportunities in this sector. On the other hand, the population who live in the LRT corridor experienced a comparable trend, with a rise from 5.6% in 2011 to 8.4% in 2021. As a part of growth in the employment market, for people living in both the LRT corridor and other part of the city had an increasing non-service working opportunities. People living in the LRT corridor have a little fewer portion working in the non-service industries. In contrast, the service industry displayed higher employment proportions throughout the study period. Compare with other part of the city, the LRT corridor which is also the city center are more likely to attract people who work in the non-service industries to live there.

In the EIA report for the LRT project, it mentioned that Regional Government planned to relocated employment opportunities into the Central Transit Corridor (Aecom, Hatch Mott MacDonald, Region of Waterloo, 2009). From 2011 to 2021, the employment density within the LRT corridor increased by 18.6% whereas the regional level remained the same. To be more specific on the service-related and high-tech industries, the increase on employment density has a range from 30%-50% (Statistics Canada, 2021; Statistics Canada, 2016; Statistics Canada., 2011). The data reveals a notable trend of rapid growth in the service industry within the LRT corridor compared to the city-wide area. Over the examined period, the proportion of employment in the service industry in the LRT corridor consistently surpassed that of the city-wide area. This suggests a greater concentration of service-related businesses and job opportunities along the LRT corridor, potentially driven by the accessibility and connectivity provided by the transportation infrastructure.

From a household perspective, corresponding to the increasing population, the number of households increased from 158,480 to 219,060, a 38.2% change from the 2001 level. Meanwhile, each home usually has 2.6 family members, which has remained stable for the past two decades. From the household income perspective, the region's median household income rose 15.48% from \$66,878 in 1995 to \$77,229 in 2015. The region's income level is always higher than the national and provincial average. Within Ontario Province, the Region of Waterloo has a faster income increase ratio, which also widens the gap between Region and Provincial income levels by 90%.

4.3.3 Region of Waterloo Transportation Results

From the EA report, the LRT’s daily ridership was estimated to be 17,000 (Aecom, Hatch Mott MacDonald, Region of Waterloo, 2009, p. 58). When the Light Rail network was introduced in June 2019 with an average daily ridership of 16,121, equating to a yearly ridership of 5.88 million before the onset of the Covid-19 Pandemic in March 2020. The ridership almost met the projected level from the EA report. In addition, the LRT system stimulated a 10% increase in the region's overall public transit ridership, with a 45% increase in ridership along the LRT corridor between June and December 2019, as compared to the previous year (Seto C. , 2020). However, the Covid-19 Pandemic greatly affected people’s life and LRT’s ridership. In 2020 and 2021, the ION LRT system had a 52.94% and 64.27% of ridership decrease compared to the 2019. By comparing with five other mid-sized cities in southern Ontario, these cities also experienced a similar scale of passenger loss in public transportation in 2020 and 2021. Compared to the passenger numbers in 2019, ridership in these cities decreased by an average of 49.1% in 2020. In 2021, compared to 2019, these cities experienced an average reduction of 55.42% in ridership.

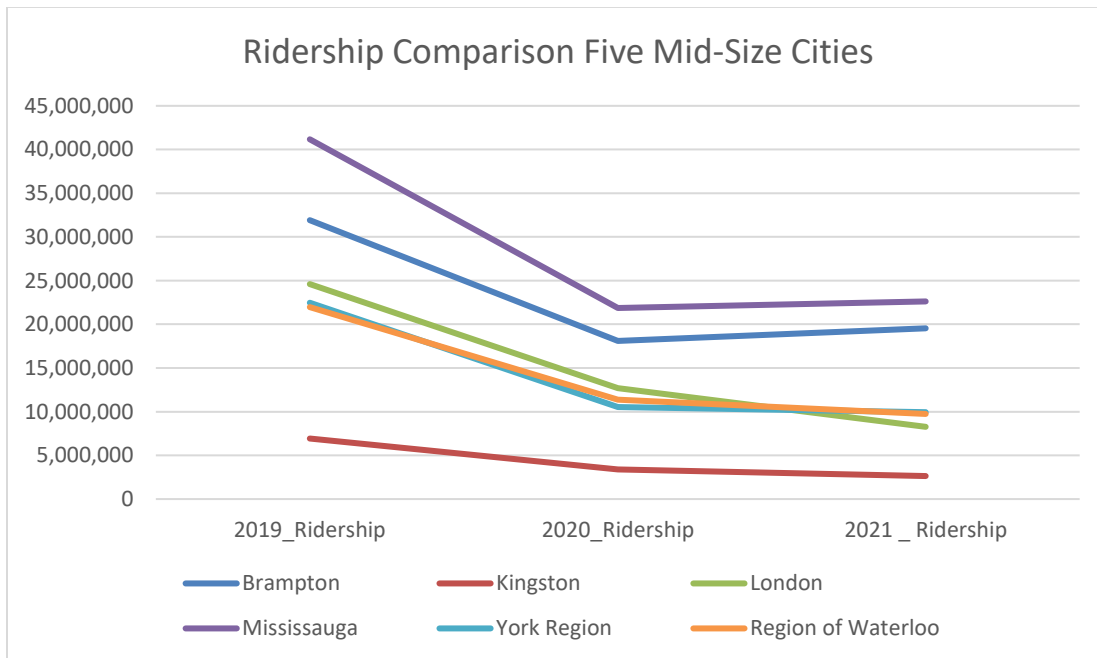


Table 4-6 Ridership Comparison Five Mid-Size Cities in Ontario (Canadian Urban Transit Association, 2021)

With the conclusion of the pandemic, ridership on the LRT system has shown signs of recovery since the latter half of 2022. Throughout 2023 and into 2024, monthly ridership has stabilized between 350,000 and 550,000 passengers. In the year 2023 alone, the total ridership reached 5.65 million, which represents 96.6% of the ridership levels observed in 2019, the year the network was first introduced.

Changing people’s travel behavior is also one of objectives that were proposed by the EA report. According to the census data, the mode of commute in the Region of Waterloo also had some changes during the past two decades. As shown in the Table 4-7, despite driving to work remaining the predominant commuting mode, accounting for approximately 80% of the working population, there is a notable decline in the proportion of individuals commuting as car passengers before 2016. Meanwhile, the usage of public transit was almost doubled during the past decades if exclude the pandemic’s impact. As the number of working populations were increasing, the number of transit user increased dramatically which refers to a continuously increasing demand for public transit network.

	Car-Driver	Car-Passenger	Public transit	Walked	Bicycle	Other
2021	81.45%	7.68%	4.62%	4.24%	0.00%	1.99%
2016	80.96%	6.74%	6.03%	4.38%	1.12%	0.78%
2011	81.63%	6.74%	5.44%	4.33%	1.13%	0.96%
2006	78.67%	9.31%	4.55%	5.08%	1.59%	0.80%
2001	81.61%	6.71%	5.18%	4.37%	1.14%	0.99%
1996	80.08%	8.62%	3.70%	5.81%	1.07%	0.72%

Table 4-7 Mode of Commute Region of Waterloo (Statistic Canada, 1996-2021)

		Car, truck or van	Carpooling	Public transit	Active transport
2021	City Wide	86.48%	7.13%	5.06%	4.71%
	LRT Corridor	78.2%	6.46%	9.35%	8.78%
2016	City Wide	75%	12.6%	6%	5.5%

	LRT Corridor	62.53%	11.76%	11.68%	14.02%
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Table 4-8 Mode of Commute LRT Corridor and Region of Waterloo (Statistic Canada, 2021)

Focusing on the LRT corridor in the City of Kitchener and City of Waterloo, the data highlights geographic disparities in the primary modes of commuting across different parts of the cities. The impact of the COVID-19 pandemic significantly affected public transit usage, with notable signs of recovery through 2021. According to the 2016 and 2021 census data (Statistics Canada, 2016; Statistics Canada, 2021), public transit usage within the LRT corridor exceeded that in other parts of the cities. Moreover, the prevalence of active transportation was higher in the LRT corridor areas, indicating a stronger preference for public transit and active modes of transportation among residents. These findings align with the goals outlined in the Regional Growth Management Strategy (RGMS) (Region of Waterloo, 2003) and the Environmental Impact Assessment (EIA) report (Aecom, Hatch Mott MacDonald, Region of Waterloo, 2009), “enhancing our natural environment, building vibrant urban places and providing greater transportation options”. Consequently, the implementation of the LRT and associated development initiatives has notably influenced residents' travel behavior, steering it toward more environmentally conscious and sustainable choices. As illustrated in the table 11, there is a shift from motorized to active transportation modes between 2016 and 2021, particularly along the LRT corridor.

Chapter 5 Conclusion and Recommendation

This research focuses on exploring the relationship between a city's initial background and the feasibility study for Light Rail projects. Using two Light Rail projects in mid-size North American Cities (the City of Buffalo and the Region of Waterloo) as case studies, this research addresses the following research questions:

- Do urban trajectories matter in evaluating LRT feasibility in mid-size cities?
- What are the commonly articulated, expected impacts of LRT projects, and how are the metrics of these impacts developed?
- What are the assessment methods used by existing feasibility studies for LRT projects?
- What factors could be considered to describe the initial conditions for a city and how should these be included in the assessment process?

Section 5.1 summarizes the main findings of the study based on the four research objectives. Section 5.2 outlines the limitations of the research. Section 5.3 discusses the contribution of this research and recommendations for planning practice. Lastly, Section 5.4 suggests the opportunities for future research.

5.1 Summary of Findings

The study identifies that a city's initial background can have a close relationship with its Light Rail project, significantly affecting its performance. LRT projects in growing cities are more likely to meet or exceed expectations, while those in declining cities often fail to achieve anticipated results. Among the LRT's feasibility study reviewed, there are three types of goals mentioned most (Transit-related Goals, Social-Economic Goals, and Environmental Goals). Specifically, transit-related goals typically are about accommodating projected travel demand, managing traffic congestion, attracting ridership for public transit and generating fare revenue to compensate part of the operation cost. Social-economic goals include stopping population loss, managing population growth, and stimulating development along the transit corridor. Environmental goals include reducing greenhouse gas emissions, improving air quality and improving sustainability. The existing feasibility studies that were reviewed in this research usually first identified a city's existing condition and then forecast the future demands. To ensure methodological consistency, standardized indicators and metrics are employed. Notably, ridership and individuals' travel behavior emerge as prominent indicators for assessing the transit-related dynamics within a city. Meanwhile, demographic statistics, employment figures, household income levels, and land development patterns constitute typical indicators utilized to gauge socioeconomic objectives. However, there is no universal metric for evaluation; metrics are typically tailored to the unique circumstances of each city.

This study then performed a comparison between two case studies with different initial backgrounds and evaluated the performance of the LRT in both cities, based on demographic changes, employment market, LRT's ridership, etc. In the City of Buffalo, which was grappling with economic decline, there was an expectation that the Light Rail Transit (LRT) system would reverse the downturn and stimulate development, particularly in downtown Buffalo. However, the outcomes fell short of nearly all the initial planning objectives. Despite the introduction of the LRT, the city continued on its recessionary path well into 2000. The population continued to decline, and there was no significant recovery in population density within the downtown area following the LRT's completion. From an economic standpoint, the city experienced a loss of jobs, particularly in the industrial sectors. Contrary to the projections made in the feasibility study, the completion of the LRT did not catalyze retail growth

within the city. Due to the poor economic performance, the average income of residents greatly fell behind the state and national average. The ridership estimates for the LRT were never realized; ridership peaked upon the system's inauguration but subsequently declined. Moreover, an increasing portion of residents opted for driving as their primary mode of daily transportation, further undermining the LRT's effectiveness.

In the Region of Waterloo, the Light Rail Transit (LRT) project was strategically designed to manage population growth and has shown considerable promise in achieving its planning objectives. Analysis indicates that the LRT corridor has become markedly more attractive to residents, evidenced by significantly higher population and population density growth rates in this area compared to other parts of the city. This corridor has also become a focal point for high-density residential and commercial developments. As anticipated in the feasibility study, local employment has seen a shift towards service industries, accompanied by an expansion in the employment market. Moreover, local income levels have continued to exceed the provincial average. Initially, LRT ridership closely approached the projected figures in the months preceding the COVID-19 pandemic. The pandemic notably impacted ridership, a trend observed across various cities in Ontario. Nevertheless, post-pandemic, the LRT's ridership recovered and aligned with the designed ridership levels. Furthermore, there has been an increase in the proportion of the population using public transit as their primary mode of commute, reinforcing the LRT's role in shaping travel behaviors in the Region of Waterloo (IBI Group; Region of Waterloo, 2019; Planning Research and Analytics, Region of Waterloo, 2022).

The findings of this research do not suggest that building transit infrastructure like Light Rail Transit (LRT) is inherently unfeasible for recession-affected cities. On the contrary, such investments can offer significant benefits, particularly in addressing equity issues within these communities. Prior studies have shown that public transit networks are primarily used by marginalized groups, including communities of color and low-income populations (Partnership For The Public Good, 2017; Geneviève , et al., 2018; Gregory , et al., 2022). The introduction of LRT systems can provide these populations with reliable transit options, enhancing their access to employment opportunities and reducing transportation barriers. This, in turn, supports economic revitalization and promotes greater

social equity within recession-stricken areas. However, the equity impacts of LRT projects are difficult to quantify and were not included in this research.

From the findings from the two case study cities, this research noticed that different initial backgrounds lead to contradictory performance of the LRT in two cities. However, in their feasibility studies, the researchers proposed similar promising demand and positive objectives for both LRT projects. The existing research did include some social-economic factors to represent the city's initial condition and perform estimation based on that. However, the existing studies failed to include the Marco Social-Economic Context and importance of the urban growth trajectory. Due to these gaps, existing research has overlooked the relationship between a city's initial background and the performance of LRT projects, leading to imprecise forecasts and the inability to propose unique, supportive plans. Especially for the recession city like Buffalo, the findings from this research noticed that the feasibility study proposed some unachievable objectives for the LRT projects.

Overall, the results from the two case study cities underscore that varying initial conditions can lead to different levels of challenges for LRT projects. The findings of this study are valuable because they highlight a systematic deficiency in current feasibility studies, which tend to overestimate the benefits of LRT without adequately considering the city's initial conditions.

5.2 Limitation of the Research

While this research explores the significance of initial background to the feasibility study of LRT projects and the relationships between initial background and LRT performance, there are several research limitations which readers should note when interpreting research findings.

The first limitation concerns data discrepancies in the census program, as the two case study cities are in different countries. In this study, data for Buffalo's LRT project was sourced from the U.S. Census, while the Region of Waterloo's LRT utilized data from the Canadian Census. Therefore, two census programs have some discrepancies which could affect the data consistency. In the United

States, the census was performed every ten years, however, the census was performed every five years in Canada. The primary limitation pertains to the disparities in data stemming from the divergent methodologies employed by the census programs of the two case study countries. This discrepancy, arising from the disparate cadences of the United States' decennial census and Canada's quinquennial census, potentially undermines data consistency. Moreover, differences in census methodologies and statistical categorizations further compound this challenge. Furthermore, the longitudinal nature of the census data utilized in this research, spanning several decades for each city, exacerbates the issue, as changes in geographical boundaries of census tracts and alterations in statistical cataloging over time introduce additional complexities.

A limitation was also identified regarding the completeness of the data of the case study LRT system. The Buffalo's LRT project was completed in 1985 and most of the planning work were completed in 1970s. However, the Region of Waterloo's LRT was opened in 2019 and most of the planning work was conducted after 2000. The data and documents for the Region of Waterloo's LRT are easy to find and get access. However, the data and documents for City of Buffalo's LRT were hard to access and less complete. The Buffalo's LRT was designed and built in 1970s and 1980s. At that time, documents and data were not digitally archived. In addition, many of the documents cannot be accessed through website. For example, the EA document for Buffalo's LRT was borrowed through the Library Network from Northwest University in a film format.

Another limitation for this study was the impact of the COVID-19 which only affected the Region of Waterloo case. The outbreak of the pandemic affects this research from two perspectives. On one hand, the 2021 Census Data and ridership data was greatly affected. The shutdown and social-distance policy greatly affected the ridership data and affected people's travel behavior. From the census data before 2021, the usage of public transit had an increasing trajectory, however, there is a huge drop in the 2021. On the other hand, the hybrid working style could have a huge impact on the demand for the public transit. This changing is unexpected external factor for both feasibility studies for LRT project.

Finally, this research is completed through secondary data from census programs, open data and related database. Some unique geographical or social context that is only known by local residence might need further discussion. In this research, for the Region of Waterloo, where the author was living in the Region, the author has firsthand knowledge of the area, having observed both the construction and inauguration of its Light Rail Transit (LRT) system. In contrast, the LRT system in Buffalo was designed and launched in the 1970s and 1980s, and the author have not had the opportunity to gather the data from the construction period.

5.3 Future Research and Recommendation

Currently, many mid-size cities in North America have proposed and implemented Light Rail Transit systems such as Calgary, Ottawa, Edmonton and Waterloo. These systems were designed to support the local development or manage the population growth. This study provides an example of the significance of the initial background success of the Light Rail project. The findings from this research show that different initial backgrounds could bring different levels of challenge to Light Rail Projects and affect the LRT's capability to alleviate other urban development issues. The findings from this research could be the starting point for future similar research which aims at verifying the findings from this research. Moreover, future research can focus on other mid-size cities in North America and examine whether the findings from this research occurred in other cities and is there any cities did a better job of forecasting their LRT's performance based on their initial background.

For local governments and planning industries, the findings in this research reveal that improvements for existing feasibility study methods are required. The existing feasibility study methods may underrate risks especially those related to recessions. For areas experiencing decline or showing trends of decline, a relatively conservative and cautious approach should be taken when forecasting the future. This research also recommends that, during the feasibility, the alternative options should not be limited to similar options like Bus Rapid Transit, Highway Expansion and Subway. The large infrastructure investment such as the LTR project not only incurs substantial financial costs but also results in significant opportunity costs for a city.

As a finding from this research, the initial background is a crucial element because it combines various aspects of city development and has deep impacts on urban development challenges and opportunities. The initial background is not only meaningful for Light Rail Transit projects but also for other infrastructure investments as well. Future Research can also replicate a similar research method and examine the feasibility study for other infrastructure investments.

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