Planning for Regional Bike Sharing: Human-scaled Mobility and Transit Integration in Urban Growth Centres

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A Major Paper
submitted to the Faculty of Environmental Studies
in partial fulfillment of the requirements for the degree of Master in Environmental Studies
York University, Toronto, Ontario, Canada

2 August 2018

Abstract

This paper argues that an integrated approach to bike sharing program implementation can yield considerably higher benefits than bike sharing operations in isolation, and can improve transit systems and urban design alike. This paper draws from literature on the Sustainable Transportation paradigm, New Urbanism and Smart Growth to argue that a transit-integrated regional approach to bike sharing can greatly contribute to a seamless regional transit system, while yielding significant benefits to local urban design and mobility as well. Such an approach can significantly enhance transit's competitiveness against the automobile, enabling transit-oriented designs of Urban Growth Centres that mitigate autocentric suburban sprawl. Employing this approach to GO Transit's upcoming Regional Express Rail (RER) and the Urban Growth Centres of the GGH can facilitate the complete communities desired in the Provincial *Growth Plan* to advance the GGH's polycentric urban network. The incorporation of bike sharing systems (BSSs) into regional transportation planning approaches provides the link that connects the regional with the local just as it connects the user from their door to the transit station. To realize its full potential in multimodal chains, bike sharing requires a high level of integration with the anchoring transit system in order to make it convenient and competitive against the personal automobile. Simultaneously, a regional transit system that targets Urban Growth Centres to integrate bike sharing at the local level helps to facilitate Smart Growth goals, complete communities, New Urbanist design; and enhances the scope of transit-oriented development (TOD). Effective BSS-transit integration requires both transit fare and station integration, and is strongly compatible with newly emerging mobility as a service (MaaS) systems for seamlessness. A coordinated package of cycling infrastructure and BSSs can significantly increase cycling rates, contribute to station integration, and improve the cycling-transit interface generally. This package is also a crucial element to local design contributions, where it is argued BSSs should be considered as a fundamental design element to Urban Growth Centres in order to facilitate New Urbanist design and improved TOD.

Foreword

Within this program, my focus of study evolved and changed as time went on. When I initially entered the program, I was more focused on renewable energy systems than where I am today. While this paper and my Plan of Study do align on multiple levels, some aspects of my initial area of concentration that pertain specifically to renewable energy production have left the focus when it comes to my final paper. Nonetheless, the other side of renewable energies is energy efficiency, which is certainly reflected in this paper. Cycling is one of the most efficient forms of transportation available; combining this with a basis of material sharing and efficiency improves further while consumption of products and fossil fuels decline. In investigating the possibilities of democratic engagement arising out of the integration of sustainable modes of transport in communities, I found that bike sharing may be one of the most democratic forms of transit in use today. Bikes are either free-floating, allowing access for anyone; or station-based, the modular design of which opens up opportunities for participatory engagement in station network design with the communities that use them.

In my area of concentration, I asked a number of key questions, of which I found answers to when researching for and writing this paper. When asking what a more sustainable transportation-energy planning nexus look like, this paper answers with the solutions provided in a Sustainable Transportation paradigm. Sustainable transportation involves sharing space more efficiently, and sharing the use of transportation modes where possible—which, as it turns out, is quite often. Whether it be sharing the space on a train or subway, or sharing the use of a publically shared bicycle, such transportation changes making their way into the status quo is a dramatic improvement to the current paradigm of privately owned, space hogging personal-occupancy vehicles and heavy fossil-fuel consumption. In answering how people's travel behaviours change when energy sources change, I find that people can consume much less if their urban environments promote the use of efficient forms of transportation as a primary mode rather than as a last resort (if promoted at all). Finally, to answer what the transition into renewable energy and smart transportation would entail—it would entail a new built environment that reprioritized compact and complete communities that are organized not around the unabated use of the automobile, but rather on effective and efficient fixed-route transit systems that reconnect the lost relationship between transportation and land use. Also in this mix is a reclaiming of the streets as a place primarily for *people*, not cars, where the public realm once again becomes the extended living space of communities; where people get about using bicycles, their feet, or chatting to neighbours on transit. Complete streets are certainly an act of social justice.

This paper relates most to my Plan of Study components two and three—Adoption of smart modes of transportation and associated infrastructure, and Smart transportation and energy systems planning and community engagement. In regards to the learning objectives of component 2; the first learning objective listed is answered wholly and completely with the thesis and arguments made in this paper. This paper explicitly calls for the use of emission-less bicycles for short-medium trips within our communities and neighbourhoods, and identifies the necessary ways to integrate bike sharing into regional transit to facilitate longer regional trips. The accommodating infrastructure for such transportation is the reintroduction of fixed-route transit systems and the establishment of complete streets that prioritize walking, cycling and transit in that order (if not cycling first). Also very clear in this paper is the effect automobiles have on the way we build our urban environments. Sprawl is a highly detrimental spatial configuration for our towns and cities in numerous ways, and this paper identifies ways to mitigate and repair sprawl's impacts by using the *Growth Plan's* Urban Growth Centres as the means to retrofit the suburbs in a Smart Growth and New Urbanist image.

In regards to the learning objectives attached to my third component; communities don't get to democratically engage in the ways energy and transportation space are defined in our current system—other than choosing which colour and model of car they want to buy. The situation is further entrenched by the anti-social and indeed anti-democratic society a car-dominant culture seems to promote. Perhaps by rejecting cars as the primary transportation mode and getting back to designing our towns and cities around how and where we want to go, democratic engagement will be not only more necessary but also more spontaneous and organic as people begin to engage with their environments and each other on a more substantial level. And finally, researching and writing this paper not only gave me the knowledge and skills to meet the requirements of CIP and OPPI, but it infused me with the passion of planning to love this field and fight for what I think is right and best for communities and the environments that we necessarily all have to share.

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1. Introduction

In the early 2000's the Province of Ontario initiated a policy mandate focused on mitigating and restoring the damage caused by suburban sprawl in the Greater Golden Horseshoe region (GGH). In this, the Provincial *Places to Grow* Act and the *Growth Plan for the Greater Golden Horseshoe* established a Smart Growth development strategy for the region, which delineated Urban Growth Centres to structure density intensification in an attempt to reverse the pattern of suburbanization. Low-density suburban sprawl fosters a number of negative effects related to the environment, economy, and the social sphere of society; with a significant amount of literature pointing to the preeminence of the automobile in today's society as a major cause. Accelerating air pollution, rendering public transit ineffective, and decreasing equitable access to transportation are just a few of the problems caused by autocentric planning practices. Following the established policy mandate, regional transportation authority Metrolinx is pushing to provide alternatives to the automobile by moving forward on a number of rapid transit projects across the region. Bus rapid transit (BRT) in Peele and York Region; light rail transit (LRT) in Toronto, Mississauga and Hamilton; and GO Transit's Regional Express Rail (RER) are all projects in some stage of delivery under Metrolinx's auspices. Transportation innovations are also coming from the private sector, where shared and flexible mobility services are increasing in prominence. The possibility of a new transportation planning and management paradigm are also emerging, under which flexible and shared mobility have the potential to fill the service gaps of fixed-route transit for effective multimodal mobility.

On a local scale, cycling has been understood as a sustainable solution to the effects of autocentric transportation. Proponents of this understanding could even be seen in the previous Ontario Liberal government under Kathleen Wynne (2013-2018). In December, 2017, the Ontario Provincial government announced a campaign to fund additional cycling infrastructure with an infusion of $93 Million throughout the province; the City of Toronto slated to receive $25.6 Million of it. These funds include provisions to expand Toronto's bike sharing program, Bike Share Toronto, by an additional 300 stations and 3000 bikes.[1] Such funding contributes to

[1] Amara McLaughlin, "Ontario ready to spend $93M to expand bike lanes, boost cycling infrastructure by 2018," *CBC News*, 4 December 2017. Url: https://www.cbc.ca/news/canada/toronto/ontario-commuter-cycling-program-1.4431461.

the multi-national road safety project *Vision Zero*, aimed at eliminating fatalities and serious injuries related to road traffic in cities throughout North America, including Toronto and across the GGH. However, with a number of cyclist fatalities throughout the City of Toronto in the spring and summer of 2018, many wonder why progress isn't happening faster. Many argue that not enough is being done to suggest that Vision Zero is being taken seriously. "You can't have a Vison Zero plan and not implement it and say that its failing. You have to actually implement it and we're not doing that," said Cherise Burda, Executive Director at Ryerson University's City Building Institute.[2] Indeed, efforts to implement more pedestrian and dedicated cycling infrastructure are lagging, with most roads still prioritized for automobile travel. While dedicated cycling infrastructure is a key component, this paper suggests that more has to give in order for real change to happen. As long as streets are designated primarily for the use of automobiles, Vision Zero will be next to impossible to accomplish alongside autocentric planning practice and sprawl. To enact effective change, this paper argues for a coordinated package of bike sharing systems (BSSs) and dedicated cycling infrastructure on a local scale, that is effectively integrated with high-order transit like GO RER on a regional scale. Culminating as a transit-integrated regional approach to bike sharing; deploying this effort across the region's Urban Growth Centres can increase cycling and safety, greatly improve the effectiveness of transit, and facilitate better urban design based on New Urbanism, Smart Growth, and TOD principles.

This paper draws on literature from the Sustainable Transportation paradigm, New Urbanism and Smart Growth to specifically look at integrating BSSs with GO Transit's upcoming RER across the region's Urban Growth Centres, and investigate the arising opportunities in mobility and land use outcomes. Here, I argue that a transit-integrated regional approach to bike sharing can greatly contribute to a seamless regional transit system, while yielding significant benefits to local urban design and mobility as well. Such an approach can significantly enhance transit's competitiveness against the automobile, enabling transit-oriented designs of Urban Growth Centres that mitigate autocentric suburban sprawl. Employing this approach to GO Transit's upcoming Regional Express Rail (RER) and the Urban Growth Centres of the GGH can facilitate the complete communities desired in the Provincial *Growth Plan* to advance the GGH's

[2] Peter Goffin, "String of recent pedestrian and cyclist deaths has public urging Toronto to make streets safer," *Global News,* 17 June 2018. Url: https://globalnews.ca/news/4279242/toronto-street-safety-cyclists-pedestrians/.

polycentric urban network. The incorporation of bike sharing systems (BSSs) into regional transportation planning approaches provides the link that connects the regional with the local just as it connects the user from their door to the transit station. To realize its full potential in multimodal chains, bike sharing requires a high level of integration with the anchoring transit system in order to make it convenient and competitive against the personal automobile. Simultaneously, a regional transit system that targets Urban Growth Centres to integrate bike sharing at the local level helps to facilitate Smart Growth goals, complete communities, New Urbanist design; and enhances the scope of transit-oriented development (TOD). Effective BSS-transit integration requires both transit fare and station integration, and is strongly compatible with newly emerging mobility as a service (MaaS) systems for seamlessness. A coordinated package of cycling infrastructure and BSSs can significantly increase cycling rates, contribute to station integration, and improve the cycling-transit interface generally. This package is also a crucial element to local design contributions, where it is argued BSSs should be considered as a fundamental design element to Urban Growth Centres in order to facilitate New Urbanist design and improved TOD. Ultimately, an integrated approach to bike sharing program implementation yields considerably higher benefits than bike sharing operations in isolation, and can improve transit systems and urban design alike.

This paper begins with an explanation of methodology, followed by a problem statement in the form of a brief overview of suburbanization, the relationship between transportation and land use, and automobile overdependence. Afterword, the paper's theoretical foundation is outlined, with overviews provided of the Sustainable Transportation paradigm, Smart Growth, transit-oriented Development, and New Urbanist design. A literature review follows, which investigates various aspects of cycling infrastructure and international bike sharing programs. The paper's argument is prefaced by a policy context section as well as an application section, which describes examples of potential Urban Growth Centre locations for early application of this approach. On this, it should be noted that the approach in this paper is written generally and intended for all Urban Growth Centres; the two examples in the application section have been identified as examples of prime candidates, pending further research and detailed planning and design. Entering into the argument of the paper, an analysis of the relationship between bike sharing systems, cycling infrastructure, and induced demand is provided as the foundation to local application. Following this is a detailed section on BSS-transit integration, which spans discussions on first/last mile solutions, integrating bike sharing programs with transportation policy and planning, the potential of bike sharing to resolve barriers to cycling-transit connections, station and fare integration, and finally mobility as a service (MaaS). Following up this paper is a section exploring the impact this approach can have to the built environment and public realm, focusing on New Urbanist design and TOD in Urban Growth Centres, and the importance of street design to good urbanism.

2. Methodology

To explore the possibilities of integrating bike sharing with regional transit and the potential impacts such an integration could have on Urban Growth Centres, an extensive literature review and interviews with bike sharing experts were undertaken. For this paper, a qualitative approach to research methodology was used. As Patricia Leavy noted in *Research Design: Quantitative, Qualitative, Mixed Methods, Arts-Based and Community-Based Participatory Research Approaches*, qualitative research approaches "value depth of meaning and people's subjective experiences and their meaning-making processes. These approaches allow us to build a robust understanding of a topic, unpacking the meanings people ascribe to their lives—to activities, situations, circumstances, people, and objects."[3] In this vein, research for this paper began with a thorough review of the documents and literature on the urban and transportation planning topics considered here, as well as any necessary provincial, municipal and regional policies that apply. Once this process was underway, a number of professional expert interviews were conducted to gain a first-hand subjective understanding and appreciation for the topics at hand. On qualitative research methodology, Leavy further noted that "qualitative research projects often follow malleable designs in which the methodology is revised in accord with new learning acquired as the research unfolds."[4] Hence, the information and perspectives gained through these interviews guided the direction of the research and the form of arguments made as the literature and policy review process continued.

The expert professional interviews for this paper were conducted both in person and remotely by telephone/Skype, with set questions sent to participants beforehand for their review. Questions

[3] Patricia Leavy, *Research Design: Quantitative, Qualitative, Mixed Methods, Arts-Based, and Community-Based Participatory Research Approaches.* (New York, NY: Guilford Press, 2017), 124.
[4] Patricia Leavy, *Research Design, 124.*

were of a mostly standardized nature, but tailored slightly to the expertise of participants and context from which they were sharing their insight. Three interviews were conducted in total, with participants spanning from within the Greater Toronto and Hamilton Area (GTHA), to the United States, and the United Kingdom. To gain an appreciation of the local regional context of bike sharing and the perspective informing its approach, the first interview conducted was with Sean Wheldrake, manager of the City of Toronto's bike sharing program Bike Share Toronto. This interview was conducted in person at the Bike Share Toronto head office. I secondly interviewed Heath Maddox, Senior Transportation Planner at the San Francisco Municipal Transportation Agency (SFMTA). This interview not only gave me insight into the key differences and similarities in transportation planning and cycling culture between American and Canadian municipalities, but also provided an understanding of a regional approach to bike sharing in the San Francisco Bay Area. As San Francisco was one of the first North American jurisdictions to experience the entrance of a private low-cost dockless bike share provider, this also gave me professional insights into their experience in the matter and the regulatory and permitting framework that the San Francisco Bay Area bike share program utilized in managing the situation. Lastly, I interviewed Project Manager Chris Slade from the United Kingdom's BikePlus, an organization similar to the North American Bike Share Association (NABSA). Interviewing Mr. Slade provided background and insight to a European perspective of bike sharing. BikePlus and Chris Slade also had a significant amount of experience with low-cost dockless bike sharing providers—the European market has been engaged longer and to a greater extent with dockless bike sharing. Hence, Chris Slade had a number of insights into regulating dockless bike sharing and the 'market-led approach' that they represent. The information attained through these interviews has been integrated into the following sections, and informs the arguments made throughout this paper.

3. Background & Theoretical Foundation

The theoretical foundation of this paper, as well as background information regarding the problem situation that it addresses, is discussed below. This section begins with providing a very brief overview of 'sprawling' suburbanization and its impacts in North America, and identifies its cause as automobile dependency and the predominance of autocentric transportation planning. This is provided in order to provide background in establishing the problem situation that the arguments in this paper seek to address. From here, the theoretical foundation of the paper's arguments is articulated. These sections, which outline integrated mobility management, smart growth and transit-oriented development (TOD), and new urbanist design, are the theoretical components that the argument in this paper draws from. All three inform the transit-integrated regional approach to bike sharing that is posited here as the first step towards a solution to sprawl, automobile dependency, and their negative effects on the public realm.

3.1 A Brief Overview of Suburbanization and the Transportation – Land Use Relationship

The dominance and prioritization of the automobile as the basic mode of transport in North American transportation planning has had a cascading effect on the relationship between transportation and land use, culminating in the facilitation of the current suburban development mode commonly known as 'sprawl'. As described by Duany, Speck and Lydon in *The Smart Growth Manual*, settlement patterns are predicated on transportation systems. Historically, the transportation-land use relationship was defined by development patterns guided by a five-minute-walk pedestrian shed, with streetcars later determining corridor structures and trains generating the nodal pattern of urban centres and early suburbs. The relationship with transportation systems hence dictated urban planning practice; settlement patterns were anchored closely to the transportation systems that made them accessible, and transportation systems were supported by the body heat of nearby settlements. However, the emergence of automobiles quickly preoccupied transportation behaviours and the practices of transportation planning, disparaging the transportation – land use relationship and allowing new development to spread thinly and without discipline.[5]

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[5] Andres Duany, Jeff Speck & Mike Lydon. *The Smart Growth Manual.* (New York, NY: McGraw Hill Professional, 2010), 3.1.

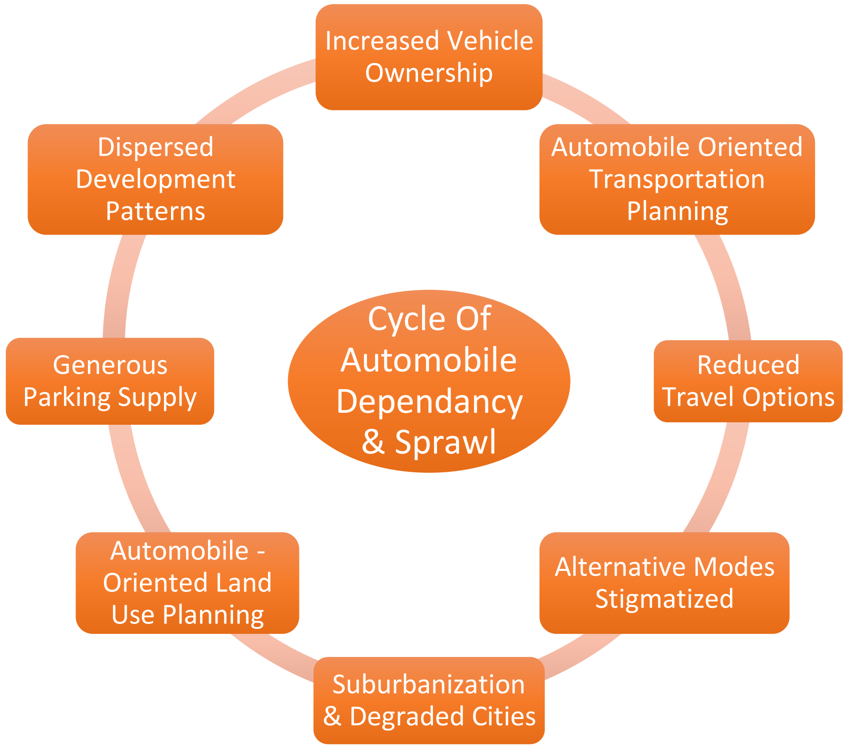


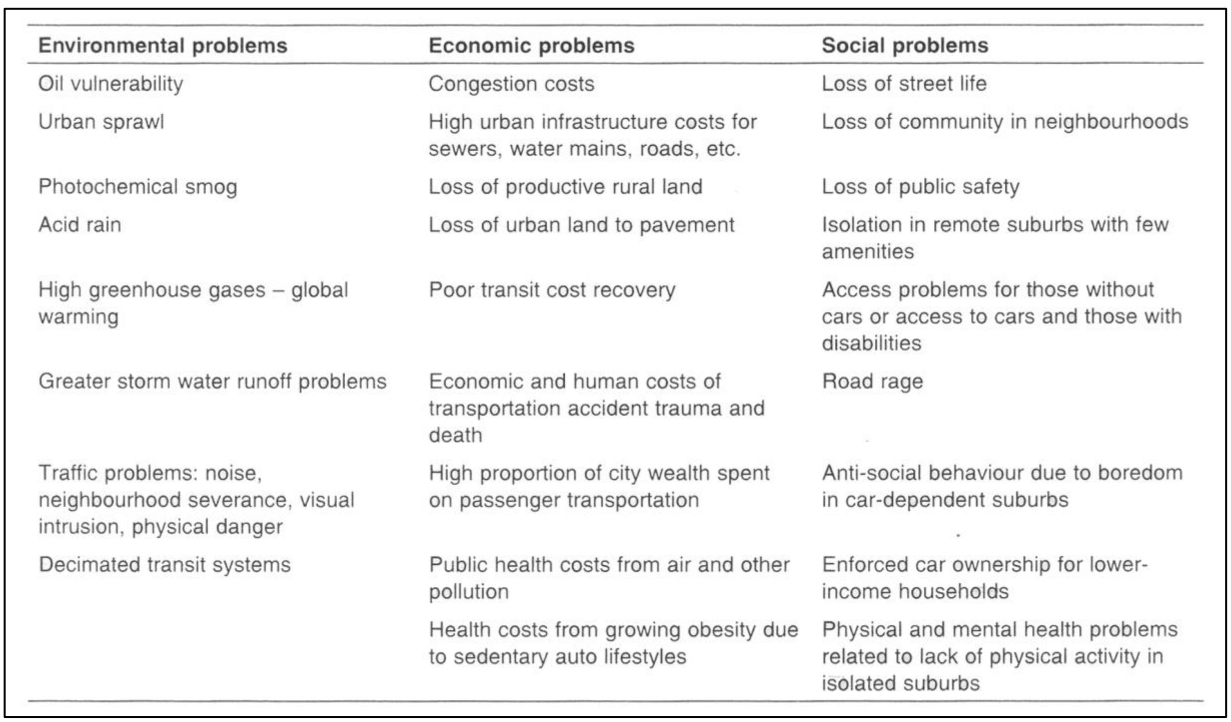
Figure 1. Source: Victoria Transport Policy Institute (2017).

Illustrated in Figure 1, the sprawling effect that autocentric transportation planning has on development patterns can be understood through a spectrum between *mobility*—the ease and efficacy of movement to access goods and services, and *accessibility*—the ability to access goods and services with the minimum amount of travel and cost.[6] When previously rural roads are improved and upgraded in urban peripheries, mobility is prioritized due to the lack of destinations in the surrounding environment. However, the newly updated road's access to cheap land escalates development pressures and the prospect of tax revenues, prompting municipalities to grant commercial and subdivision rezoning requests around an auto-dependent infrastructure environment.[7] Soon, low-density suburban development patterns arise from developers capitalizing on inexpensive and abundant land. To satisfy the transportation needs of growing populations, incremental advances in mobility (i.e. increased road widths, travel speeds and parking supply) reinforce patterns of dispersed land use and lengthy travel distances, to the detriment of accessibility. As Todd Litman of the Victoria Transport Policy Institute wrote, the

[6] Duany, Speck & Lydon, *The Smart Growth Manual*, 3.7.
[7] Ellen Dunham-Jones & June Williamson, *Retrofitting Suburbia: Urban Design Solutions for Redesigning Suburbs* (New Jersey: John Wiley & Sons, 2011), 82.

low-cost of greenfield development "favors automobile travel and reduces the utility and efficiency of other transport modes." Through their transformation, auto-dependent rural environments enable low-density development that limits the ability to access goods and services by walking or biking and makes public transit difficult to provide. Meanwhile, patterns of autocentric low-density development continue to favor greenfield, urban fringe development where land prices are lower. Left unchecked this development pattern escalates and automobile-oriented planning becomes self-fulfilling: "practices to make driving more convenient make alternatives less convenient and increase automobile-oriented sprawl."[8] The overemphasis of mobility is described by Schiller, Bruun and Kenworthy as 'hypermobility.'[9] Hence, the establishment of an autocentric transportation planning philosophy, hypermobility, and the elimination of fixed guideways and rail-based transport for most travel removed the anchoring transportation structure that previously organized land use.

Today, hypermobility has gradually reduced many transit systems—particularly bus services—to



Environmental problems	Economic problems	Social problems
Oil vulnerability	Congestion costs	Loss of street life
Urban sprawl	High urban infrastructure costs for sewers, water mains, roads, etc.	Loss of community in neighbourhoods
Photochemical smog	Loss of productive rural land	Loss of public safety
Acid rain	Loss of urban land to pavement	Isolation in remote suburbs with few amenities
High greenhouse gases – global warming	Poor transit cost recovery	Access problems for those without cars or access to cars and those with disabilities
Greater storm water runoff problems	Economic and human costs of transportation accident trauma and death	Road rage
Traffic problems: noise, neighbourhood severance, visual intrusion, physical danger	High proportion of city wealth spent on passenger transportation	Anti-social behaviour due to boredom in car-dependent suburbs
Decimated transit systems	Public health costs from air and other pollution	Enforced car ownership for lower-income households
	Health costs from growing obesity due to sedentary auto lifestyles	Physical and mental health problems related to lack of physical activity in isolated suburbs

Figure 2. Negative Outcomes of Hypermobility. Source: Schiller, Bruun & Kenworthy (2010).

[8] Todd Litman – Victoria Transport Policy Institute, "Evaluating Transportation Land Use Impacts: Considering the Impacts, Benefits and Costs of Different Land Use Development Patterns," (July 2017): 11, Url: http://www.vtpi.org/landuse.pdf.

[9] Preston L. Schiller, Eric C. Bruun & Jeffrey R. Kenworthy. *An Introduction to Sustainable Transportation: Policy, Planning, and Implementation.* (Washington, D.C.: Earthscan Ltd., 2010), 3.

“mere shadows in the overall transportation system,” bringing about “severe environmental, economic and social outcomes.”[10] The problems associated with automobile overdependence are illustrated in Figure 2. Suburban transit services continue to suffer from a vicious cycle of low ridership directly related to autocentric urban planning and the decoupling of transportation and land use. The low-density built environment of suburban areas that often lack internal destination points force marginalized local route transit systems to stretch their resources thinly across a sprawling service area, making quality frequent service too costly. Without sufficient trip generator concentrations to focus transit, the inconvenient service pushes those who can afford it further towards car-use.[11] This has an important impact on equitable access to goods and services, which depend on the effectiveness of transportation systems as well as good urban spatial organization.[12] Yet, with their high price tags and the sprawling and disparate built environments they create, cars further perpetuate the inequity of access as transit service deteriorates.

The social repercussions of automobile overdependence also have a significant impact on society, though less obvious and understood as environmental and economic outcomes. The requirements of automobile-dominant transportation systems—parking structures, widened roads, concrete barriers, and narrowly-timed pedestrian crossings—create the kinds of defensive environments in many urban centres that are designed for cars but hostile to people. Suburbs, then, become a place for many people to escape the hostility of the car-oriented busy city. In his 1996 book *Home from Nowhere: Remaking Our Everyday World for the 21st Century*, James Kunstler wrote that the primary characteristic of suburbs “was not of an organically real town, nor a civic space, but a place of fantasy and escape.”[13] Similarly, Hugh Mackay wrote that suburban life is essentially a “defensive form of escapism: a retreat to the comfort, privacy and, above all, security of home base . . . There is a growing emphasis on entertainment and recreation equipment being installed in the home to minimize the need to go out . . . we developed a compensatory obsession with the notion of privacy, which in turn, further fuelled the

[10] Schiller, Bruun & Kenworthy. *Sustainable Transportation*, 7.
[11] Montgomery, *Happy City*, 201.
[12] Schiller, Bruun & Kenworthy, *Sustainable Transportation*, 16.
[13] James H. Kunstler, *Home from Nowhere: Remaking Our Everyday World for the 21st Century* (New York, N.Y.: Simon & Schuster, 1996), 32.

fortress mentality."[14] Mackay later continued, "we may complain about the loss of a sense of belonging to a local community; but, by our perfectly understandable enthusiasm for the car, we've taken such giant strides away from a communal life that we can hardly expect the community to re-emerge all by itself."[15] Following this thought, Schiller, Bruun and Kenworthy suggested that if the social effects of automobile overdependence reduce people's "capacity to function in a participatory society, lose their sense of being 'citizens', then it is more difficult to enact the kind of policies and programmes needed to address these problems."[16] Hence, with the prioritization of the automobile comes a "logical extension or expression of a declining public realm in cities," and the privatization of daily life that is most acute in suburbs.[17] Preventing or— as some might suggest is more accurate— repairing the outcomes described by these authors is the call to action that drives this paper.

3.2 Theoretical Foundation

While the problems associated with sprawl and autocentric transportation planning are many, this section outlines the basis of an approach that intends to provide solutions to at least some. It wishes to re-establish walking and cycling as the basis for transit systems that have historically

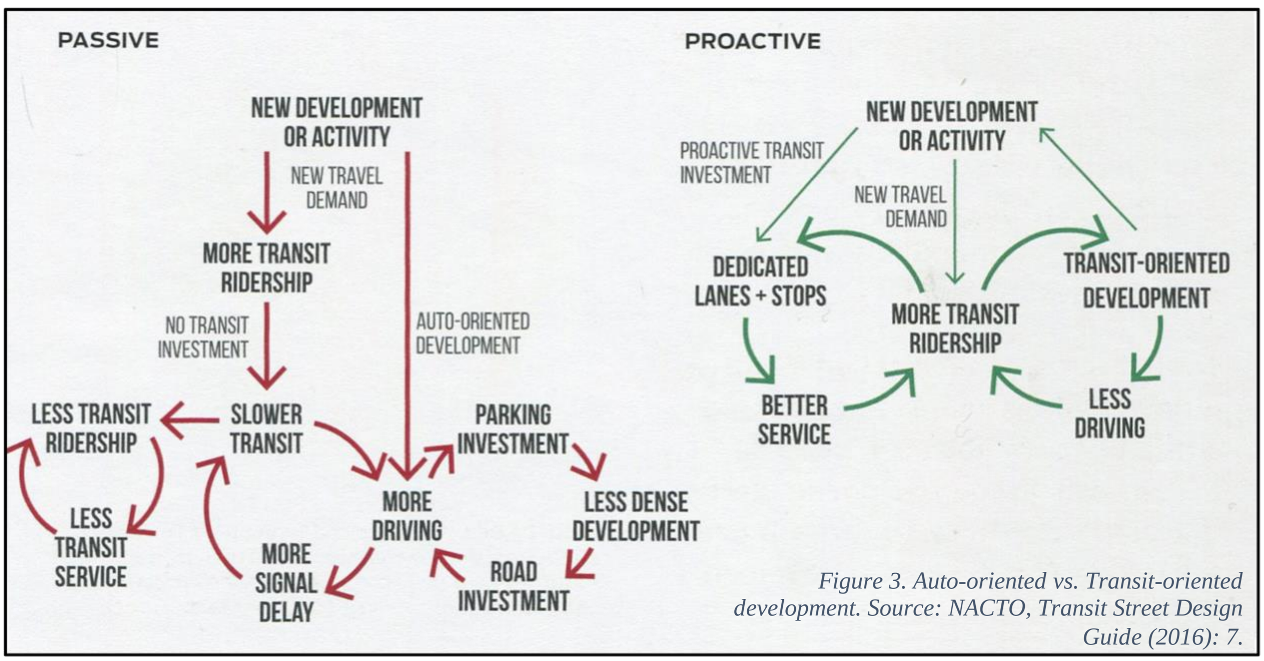


Figure 3. Auto-oriented vs. Transit-oriented development. Source: NACTO, Transit Street Design Guide (2016): 7.

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[14] Hugh Mackay, *Reinventing Australia: The Mind and Mood of Australia in the '90s,* (Sidney, Au.: Angus & Robertson, 1993).
[15] Hugh Mackay, "The Future Stops Here," *The Weekend Australian: The Weekend Review,* September 1994, 16.
[16] Schiller, Bruun & Kenworthy, *Sustainable Transportation,* 13.
[17] ibid., 14.

demonstrated synergies between people and settlement patterns.[18] As Figure 3 illustrates, a proactive approach that re-anchors land use and transit systems enables effective service and reorients growth away from auto-oriented sprawl and instead to transit-supportive densities and design. This can curb the process of suburbanization, reconnect the virtuous transit cycle and lay the foundation for human-scaled mobility. With a focus of applying these ideas to Urban Growth Centres throughout the Greater Golden Horseshoe (GGH) region, the arguments and treatments of this paper are based within three overall conceptual frameworks: (1) the Sustainable Transportation paradigm, (2) Smart Growth and transit-oriented development, and (3) New Urbanist design. These concepts are described in the following sections.

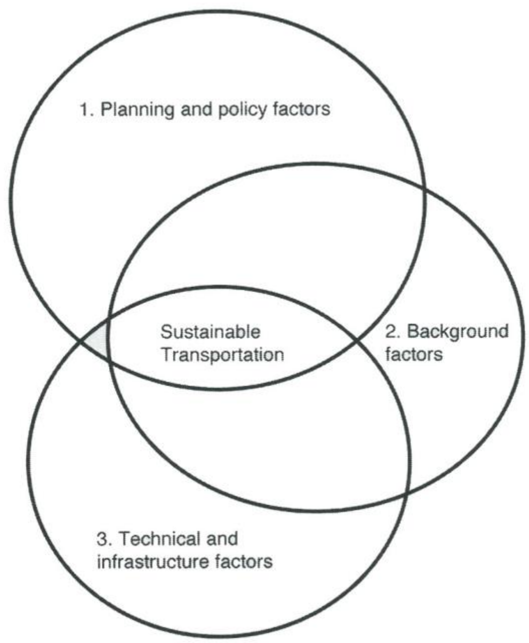
3.2.1 Sustainable Transportation Paradigm

In their book *An Introduction to Sustainable Transportation: Policy, Planning &* Implementation, Schiller, Bruun and Kenworthy argue for the implementation of a new paradigm of Sustainable Transportation (ST). This new ST paradigm is a fundamental aspect of this paper's approach. The new ST paradigm is a comprehensive approach to transforming the current business-as-usual (BAU) situation in transportation, and to some extent encompasses the remaining two conceptual frameworks that follow. Schiller, Bruun and Kenworthy explained that since the current BAU approach to transportation planning "is reductionist and tends to treat modes and facilities in isolation," ST adopts a multifaceted and integrated approach. This approach is based on the following guiding principles: (1) Stressing accessibility over mobility: almost a complete reversal of the current BAU paradigm; (2) Social equity: informing and ensuring planning is sensitive to a range of societal and cultural issues; (3) Land use strategies and impacts are addressed and accounted for in all planning processes, and; (4) Eliminating market and pricing distortions: for example, failures of taking into account the real costs of

[18] Schiller, Bruun & Kenworthy, *Sustainable Transportation,* 78.

automobile use, and to acknowledge the many benefits of transit systems to non-users.[19] A visual representation of the ST paradigm is provided in Figure 4.

In reference to the issues of autocentric transportation planning and sprawl identified in the previous section, Schiller, Bruun and Kenworthy argued that implementing a new ST planning paradigm has "the capacity to not only stop bad transportation and planning practice in order to avoid further damage, but also the capacity to begin a process of regeneration, repair and renewal."[20] Though interrelated, Schiller, Bruun and Kenworthy organize these processes of regeneration, repair and renewal (RRR) into the two categories—the physical environment, and the social and cultural environment. These categories are described in detail and a number of RRR tactics are suggested and outlined. However, for the purposes of this paper, these tactics will be listed without going into further detail. Under the



The new paradigm of integrated planning can be graphically understood as a Venn diagram depicting the intersection of three circles: background factors; planning and policy factors; and technical and infrastructure factors.

Circle 1: Planning and policy factors

- Critical event
- Policymakers, integrated policy making, policy adequacy
- Citizens and community leaders
- Careful analysis, economic evaluation, impacts
- Scenario building, evaluation of all options
- Vision of a preferred future, backcasting to inform planning
- Appropriate planning structure, motivated staff
- Deliberative planning
- Good data, evaluation
- Soft path / mobility management orientation
- Effective communications

Circle 2: Background factors

- History, heritage, culture and values
- Geography–topology
- Accountable governance systems
- Social organization
- Existing transportation and land-use systems

Circle 3: Technical and infrastructure factors

- Appropriate infrastructure and energy sources
- Availability of appropriate hardware
- Appropriate standards and measurements
- Orientation and skill sets of technical personnel
- Existing built environment
- Technical aspects of environmental impacts assessment

Figure 4. The New Sustainable Transportation Paradigm. Source: Schiller, Bruun & Kenworthy (2010).

[19] Schiller, Bruun & Kenworthy. *Sustainable Transportation,* 228-9.
[20] ibid., 236.

physical environment, the following tactics are suggested: car-free zones, traffic calming, complete streets, freeway removal, conversion of shopping malls and parking lots, and integrating transit systems with a more human- and ecologically oriented public realm. For RRR of the social and cultural environment, Schiller, Bruun and Kenworthy identify: active transportation and healthy communities by design, car-free movements, car sharing, and overcoming transportation access inequities.[21]

A key tool in the ST paradigm's repertoire is mobility management. Mobility management often involves improvements in public transportation, and supports trip reduction strategies and improved intermodal connections. Importantly, mobility management promotes the expansion and integration of mobility options, such as walking, bicycling, ridesharing, car sharing and taxi services. While Schiller, Bruun and Kenworthy identify a number of mobility management strategies, for the purposes of this paper the most important strategies relate to the categories of (a) "improving and expanding travel options" and (b) employing "land use solutions to transportation problems [such as] smart growth and multimodal land use development."[22]

Using mobility management and a number of other tools and tactics to move forward, the new ST paradigm sets a priority agenda that, among others, includes: "(1) The unequivocal need for strategic increases in density and mixed land uses, not across an entire city, but certainly at critical nodes or sub-centres to develop a polycentric urban form; (2) The need to prioritize investment in transit, walking and cycling in a biased way to overcome many decades of neglect and favouring of private automobiles, and; (3) The central importance of the public realm and its influence on non-motorized mobility and the social life of the city."[23]

3.2.2 Smart Growth & Transit-oriented Development

As a primary component of Smart Growth concepts, which are founded upon the traditional mixed-use neighbourhood, Smart Growth and Transit-oriented Development (TOD) can be viewed as a reinvention rather than something new. Both New Urbanists and Smart Growth advocates argue it was the abandonment of the traditional neighbourhood model in favor of the novelty of automobiles that led to the current ecological, economic and social crises that make

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[21] ibid., 236-48.
[22] ibid., 224.
[23] ibid., 253.

their movements necessary.[24] Table 1 provides an overview of sprawl versus smart growth principles. Central to their toolkit is the concept of TOD, which uses purpose-built transit infrastructure and express fixed-route public transit to "anchor a more environmentally- and socially-responsible urban form and help achieve more sustainable outcomes" of urban development. In reaction to the urban and transportation changes created by automobiles, TOD ultimately aims to reinvent an older form of streetcar suburbs to curb automobile overdependence, sprawl and their negative effects.[25] Widely defined as "compact, mixed-use developments with high-quality walking environments near transit facilities," TODs are designed to capture more trips internally and encourage more walking, cycling and transit trips by "creating an urban form that is relatively high density, mixed in terms of different land uses, served by high quality transit, and with pedestrian-friendly designs."[26] The goals and benefits of

Attribute	Sprawl	Smart Growth
Density	Lower-density	Higher-density.
Growth pattern	Urban periphery (greenfield) development.	Infill (brownfield) development.
Activity Location	Commercial and institutional activities are dispersed.	Commercial and institutional activities are concentrated into centers and downtowns.
Land use mix	Homogeneous land uses.	Mixed land use.
Scale	Large scale. Larger buildings, blocks, wide roads. Less detail, since people experience the landscape at a distance, as motorists.	Human scale. Smaller buildings, blocks and roads, care to design details for pedestrians.
Transportation	Automobile-oriented transportation, poorly suited for walking, cycling and transit.	Multi-modal transportation that support walking, cycling and public transit use.
Street design	Streets designed to maximize motor vehicle traffic volume and speed.	Streets designed to accommodate a variety of activities. Traffic calming.
Planning process	Unplanned, with little coordination between jurisdictions and stakeholders.	Planned and coordinated between jurisdictions and stakeholders.
Public space	Emphasis on the private realm (yards, shopping malls, gated communities, private clubs).	Emphasis on the public realm (streetscapes, sidewalks, public parks, public facilities).

This table compares Sprawl and Smart Growth land use patterns.

Table 1. Source: Victoria Transport Policy Institute (2017).

mixing uses in TOD are multifaceted, ranging from increasing diversity, safety, and a sense of community and place, to decreasing vehicle kilometers travelled (VKT), increasing walkability

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[24] ibid., xv-xvi.

[25] John Black, Kam Tara, Parisa Pakzad, "Planning and Design Elements for Transit Oriented Developments/Smart Cities: Examples of Cultural Borrowings." *Procedia Engineering 142* (2016): 4-5.

[26] Reid Ewing et al., "Trip and Parking Generation at Transit-Oriented Developments: Five US Case Studies," *Landscape and Urban Planning 160* (2017): 70.

and improving the cost-effectiveness of public transit.[27] The anchoring transit facilities in TOD ideally interface heavy rail or regional express rail (RER), light rail transit (LRT), and/or bus rapid transit (BRT) systems in order to connect regional centers, which, they tend to create or enliven.[28]

Depending on level of service, TOD areas generally span a radius of approximately 0.5–1km from a transit station and feature a small block parameter and a fine-grained network of thoroughfares. TOD streets allocate traffic-calmed road space and signal timing primarily to facilitate convenient walking and cycling. TODs are often characterized in terms of the *six D variables*, which all bear a relationship to travel demand: density, land-use diversity, design, destination accessibility, distance to transit, and demand management,[29] the latter of which requires the alteration of parking requirements. Parking can play a critical role in the functionality and quality of an urban space, distorting or even determining the urban form of suburbs. Surface parking lots tend to discourage walking, and inhibit the mix of uses and compactness required for the human-scale of good urbanism. The effects of parking lot over-scaling have been especially exacerbated by municipal minimum parking requirements.[30] In TOD however, minimum parking requirements for developments are replaced with maximum parking requirements and, ideally, requirements for safe bicycle parking are established as well. Where car parking is provided, costs are 'unbundled' and full or near-full market rates are charged.[31]

In a review of the trip and parking generation rates of what the researchers call the five leading TODs across the United States (Englewood, Denver; Wilshire/Vermont, Los Angeles; Fruitvale Village, San Francisco; Redmond TOD, Seattle; and Rhode Island Row, Washington, D.C.), Reid Ewing et al. found all locations generated "significantly lower vehicle trips than predicted by the American Institute of Transportation Engineers (ITE), upwards of 65% lower than ITE's suburban, auto-oriented developments" relative to the density of residential and commercial units, as shown in Table 2. In almost all cases, the TODs sampled also provided much less

[27] Dunham-Jones & Williamson, *Retrofitting Suburbia*, 109.
[28] Duany, Speck & Lydon, *The Smart Growth Manual*, 3.4.
[29] Reid Ewing et al, "Trip and Parking Generation at Transit-Oriented Developments," 75; Ewing, Reid & Robert Cervero. "Travel and the Built Environment." *Journal of the American Planning Association 76:3* (2010).
[30] Galina Tachieva, *Sprawl Repair Manual* (Washington, D.C.: Island Press, 2010), 229.
[31] "Is It Really TOD?" TDM Encyclopedia – Transit Oriented Development, Victoria Transport Policy Institute, last updated 18 July 2017, http://www.vtpi.org/tdm/tdm45.htm.

parking than recommended in ITE guidelines, yet found that demand for parking was uniformly well below supply levels.[32] It should be noted that within these TODs, car trips are not entirely eliminated, but rather reduced. This is reflective of the aim of TOD and smart growth principles more broadly: the intention is not to eliminate automobiles as a transportation mode, but rather to rebalance street use and modal shares to genuinely accommodate other modes as well.

Average Vehicle Trip Reductions Relative to ITE Rates.

TOD	ITE vehicle trips	Actual vehicle trips	% of ITE trips	% reduction
Redmond	1,767	661	37.4%	62.6%
Rhode Island Row	5808	2,017	34.7%	65.3%
Fruitvale	5899	3,056	51.8%	48.2%
Englewood	13,544	9,460	69.8%	30.2%
Wilshire/Vermont	5180	2,228	43.0%	57.0%

Table 2. Source: Ewing et al. (2017).

That said, the sampled TODs are exemplary, but of course not perfect. Ewing et al. note that all five TODs contain a diverse land-use mix, include public spaces, sidewalks, trees, curbside parking, small building setbacks and other effective pedestrian-oriented design features. All TODs minimize distance to transit and maximize destination accessibility, with four of five providing 20% affordable housing units. However, the commercial mixed-use is "only moderately high" at Fruitvale, and residential density is "considered high only at Wilshire/Vermont and Redmond." Moreover, the TODs provided in the study all lacked coordinated attention to significant bicycle infrastructure, focusing primarily on pedestrian connections to transit. With the lower densities at three TODs and the overall lack of dedicated cycling infrastructure representing "a lost opportunity from a transit-supportive standpoint,"[33] this case study nevertheless demonstrates the effect of reconnecting transportation and land use using pedestrian- and transit-focused design can have on automobile use and transportation behavior. Ways to improve TOD design to better accommodate cycling will be addressed in a later section.

3.2.3 New Urbanist Design

New Urbanism identifies and addresses many issues under the assumption that their solution

[32] Reid Ewing et al., "Trip and Parking Generation at Transit-Oriented Developments," 73-4.
[33] ibid., 75.

"requires they be worked out together."[34] However, as this paper deals primarily with transportation and its relationship with land use, this is where this section's focus will be. New Urbanism is not anti-car, but rather about focusing on and rejuvenating short trips—the typical trip—by providing multiple enjoyable options for transport. While not focusing primarily on cycling, New Urbanist designs focus on walkability that results in places becoming "more livable, driveable, and friendly to bicycles and pedestrians" alike.[35] New Urbanism acknowledges that people who live in areas with a tight grid of streets and a mixture of land uses walk more, use transit more, and take half as many automobile trips compared to those who live in typical outer-edge suburbs. Indeed, the suburban landscape is hostile to mobility by any mode, even including the automobile. Thus, New Urbanist road systems encourage compact, transit-oriented development on adjacent land and serve pedestrians, bikes, transit and cars.[36]

To give neighbourhoods a social identity and sense of community, New Urbanism stresses the importance of public space in the spatial center of neighbourhoods. It aims to contain complete neighbourhoods within a 5- to 10-minute walking radius; balancing a mix of activities such as shopping, work, school, recreation, and all types of housing; and gives priority to the creation of public space.[37] Priority should also be given to siting major activity centres and commercial uses as close as possible to transit stops, within catchment areas that range from 0.4-0.8km but can grow based upon the quality of pedestrian environment.[38] Clustering these neighbourhoods together with a transit-oriented design can create a larger town, city, or regional network that "provides access to major cultural and social institutions, a variety of shops, and the kind of broad job base that can be supported only by a substantial population of many neighbourhoods."[39] Similarly, districts parallel the neighbourhood in structure but maintain an identifiable focus of land use that "provides orientation and identity." They preclude the full range of activities of a neighbourhood but still afford a range of complimentary activities to

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[34] Jonathan Barnett, "What's New about the New Urbanism?," in *Charter of the New Urbanism,* ed. Michael Leccese & Kathleen McCormick (New York, N.Y.: McGraw-Hill, 2000), 6.
[35] G.B. Arrington, "Eight," in *Charter of the New Urbanism,* ed. Michael Leccese & Kathleen McCormick (New York, N.Y.: McGraw-Hill, 2000), 59.
[36] Arrington, *eight,* 61.
[37] Elizabeth Plater-Zyberk, "Eleven," in *Charter of the New Urbanism,* ed. Michael Leccese & Kathleen McCormick (New York, N.Y.: McGraw-Hill, 2000), 79-81.
[38] William Lieberman, "Fifteen," in *Charter of the New Urbanism,* ed. Michael Leccese & Kathleen McCormick (New York, N.Y.: McGraw-Hill, 2000), 102.
[39] Elizabeth Plater-Zyberk, "Eleven," 79-81.

support the district's primary identity. The district also focuses on public spaces, such as plazas, squares and sidewalks, that "reinforce a sense of community among users, encourage pedestrians, and ensure security."[40]

New Urbanism identifies the 'the connected street network" as essential to its design. This is to encourage walking, biking, transit, local trips, and reduce traffic bottlenecks throughout the system. In short, the connected street network ensures that local traffic can stay local, without the need for arterials to reach farther amenities; ensures traffic is more direct and efficient; helps create and nourish public town centres; and creates the ideal environment for walking and safe cycling, the wide variety of streets ensuring the highest dispersion of traffic and negating the use of hostile arterial roads.[41] Moreover, the connected street network "designed for pedestrians, bicyclists, and drivers also encourage the casual meetings among neighbours that help form the bonds of community."[42] These principles of design and planning, as well as those from the previous two sections, serve to inform the perspectives and arguments that follow throughout this paper.

4. LITERATURE REVIEW: CYCLING, INFRASTRUCTURE & BIKE SHARING

4.1 Cycling Infrastructure & Ridership

Effective bike lanes are widely known amongst planners and urbanists to promote the uptake of cycling, particularly for women and children, and increase the safety of cycling both perceived and actual.[43] Defined in NACTO's *Urban Bikeway Design Guide* as "a portion of the roadway that has been designated by striping, signage, and pavement markings for the preferential or exclusive use of bicyclists," bike lanes allow cyclists to ride at their preferred speed without interference from motor traffic conditions, and facilitate predictable behavior and movements between bicyclists and motorists.[44] Indeed, some experts believe increases in density and connectivity of bike lane networks "offer the most promising starting point for built environment

[40] ibid., 81-2.
[41] Walter Kulash, "Twelve," in *Charter of the New Urbanism,* ed. Michael Leccese & Kathleen McCormick (New York, N.Y.: McGraw-Hill, 2000), 83-85.
[42] Plater-Zyberk, "Eleven," 81.
[43] Cyrille Médard de Chardon, Geoffrey Caruso, Isabelle Thomas, "'Success' Determinants," 206.
[44] National Association of City Transportation Officials (NACTO), *Urban Bikeway Design Guide* 2nd Ed. (Washington DC: Island Press, 2014), 1.

interventions intended to encourage cycling in urban centers."[45] Moreover, cycling infrastructure is highly cost effective when compared to infrastructure for automobiles. Building and maintaining cycling infrastructure costs an estimated one tenth or less of a paved street, especially when included in street construction or reconstruction.[46] However, the ability of bike lane network enhancements to encourage new cycling may be diminished if design consideration is not given to physically or at least spatially separating bike lanes from traffic on busier streets, rather than just painted lines.

4.1.1 Bike Infrastructure Hierarchy

Describing the various degrees of separation within cycling infrastructure, this section ultimately posits that dedicated, separated cycling infrastructure is most ideal for BSS users connecting to transit. Indeed, numerous studies indicate that the quality of cycling infrastructure, with a higher degree of separation or exclusivity, is preferred by cyclists for general transportation by both men and women, especially for accessing transit stations."[47] Protected bicycle lanes can vary in degree of separation; ranging from painted lateral buffers, to raised curbs, to simultaneously vertical and lateral separations, with numerous designs between. For laterally buffered bicycle lanes, NACTO notes bicycle symbols and arrow markings are generally used to define the bike lane and designate the portion of street for cyclists. Buffers are marked with two solid white lines ideally 3ft (.91m) in width with diagonal hatchings, to allow space for cyclists to safely pass each other while separating cyclists from fast-moving vehicles and the door-range of adjacent parked cars.[48] In terms of the bicycle lane itself, Toronto's *Complete Streets Guidelines* recommends a 1.8m lane width, while the suggested minimum width is 1.5m.[49] Appealing to an even wider spectrum of the public, bike lanes protected with a physical barrier—otherwise known as cycle tracks—are designed primarily to improve perceived comfort and safety on streets that would otherwise stress or dissuade cyclists due to motor traffic. While including all separation treatments as buffered bike lanes, cycle tracks also include a physical barrier within buffers such as a tubular bollard, movable planters, or a raised curb/traffic island. Depending on the

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[45] Lindsay M. Braun et al. "Short-term Planning and Policy Interventions to Promote Cycling," 181.
[46] Schiller, Bruun & Kenworthy, *Sustainable Transportation*, 93.
[47] Greg Phillip Griffin & Ipek Nese Sener. "Planning for Bike Share Connectivity," 4.
[48] NACTO, *Urban Bikeway Design Guide*, 10-11.
[49] City of Toronto. *Toronto Complete Streets Guidelines: Making Streets for People, Placemaking and Prosperity*. 1st ed., vol. 1 (2017), 95.

constraints of the street, on-street parking can also be reoriented as a barrier to protect cyclists if street width allows. Unlike standard bike lanes, cycle tracks are uniformly located curbs-side, may be one- or two-way, and may be at street level, sidewalk level, or an intermediate level. Including pavement colouration in potential conflict areas such as intersections, and adding vertical separation to cycle tracks can further delineate uses and increase the perception of safety and comfort.[50] In considering what type of cycling infrastructure to implement for a specific urban context, Figure 5 illustrates the *Ontario Traffic Manual Book 18* recommendation of using a metric based on speed and volume of motorized traffic on the street: higher car speed and volumes = higher cyclist risk = increased separation and protection.[51] While costs vary depending on the degree and quality of separation and protection, protected bike lanes of any variety are relatively cost-effective compared to other infrastructure improvements, with even the cheapest options delivering high cost/benefit ratios if well planned and in their appropriate contexts. Research shows that beyond the painted buffer, popularity and cyclist uptake continuously increases with further separation and protection. In a 2011 survey, almost 9 out of 10 cyclists in Portland preferred a buffered bike lane to a standard one, and 7 out of 10 indicated they would go out of their way to ride on a buffered bike lane over a standard lane.[52]

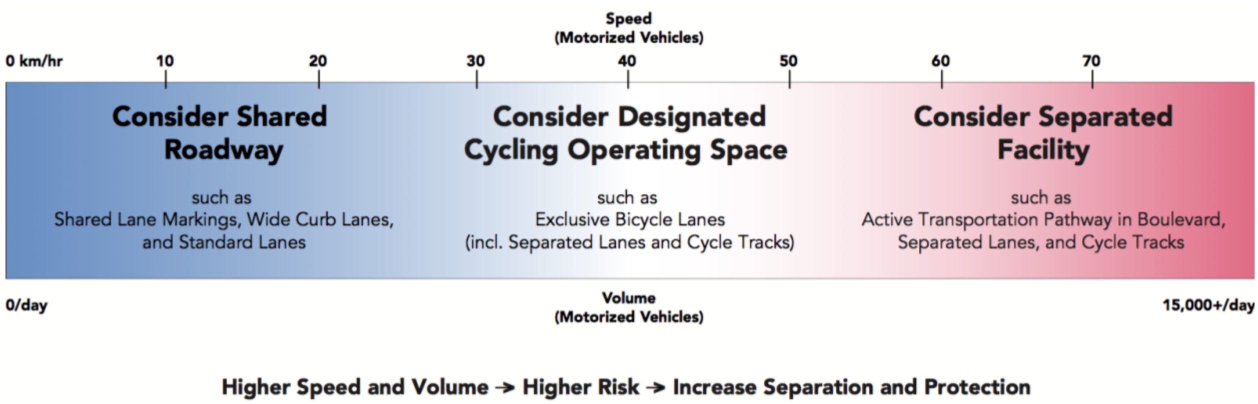

Figure 5. Source: Toronto Complete Streets Guidelines (2017) - Adapted from OTM Book 18.

4.1.2 Catalytic Infrastructure: Lessons from Portland

Traffic planners in Portland, Oregon were some of the first in North America to discover the significant latent demand for cycling amongst the general population, and the what type of

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[50] NACTO, *Urban Bikeway Design Guide*, 27-39.
[51] City of Toronto. *Toronto Complete Streets Guidelines*, 95.
[52] NACTO, *Urban Bikeway Design Guide*, 10.

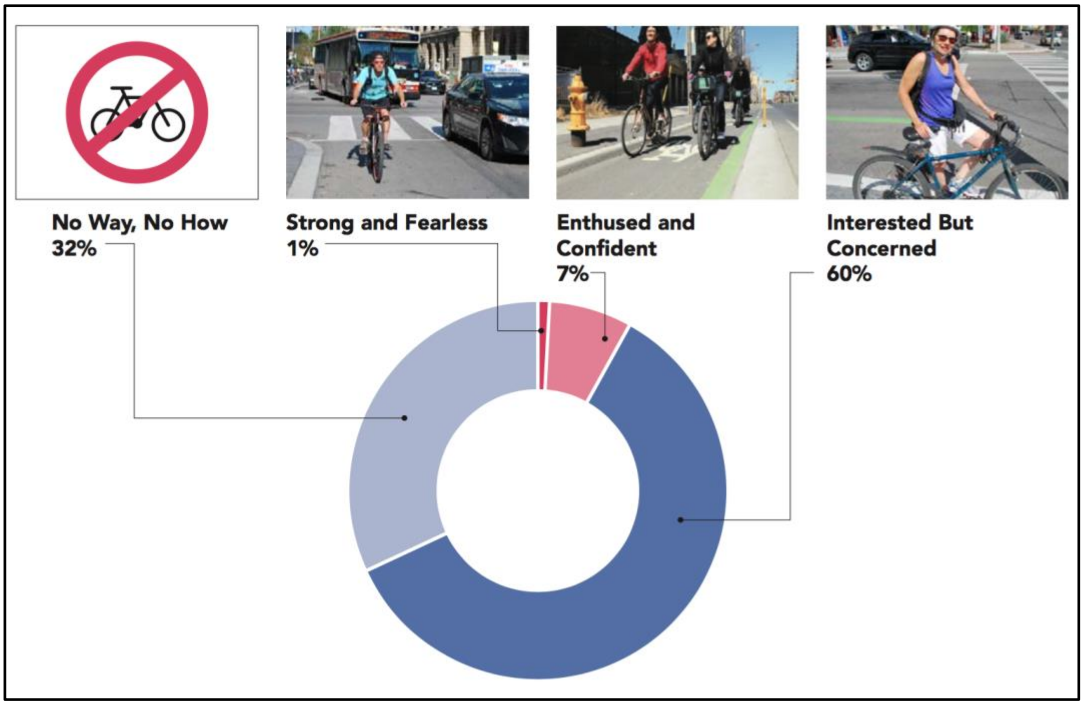

Figure 6. Four Types of Cyclists. Source: Toronto Complete Streets Guidelines (2017): 94.

cycling infrastructure necessary is necessary to support them. Before the turn of the century, the city had painted kilometers of bike lanes along busy roads in an effort to coax more citizens onto bikes. Yet by the mid-2000s the city had only seen a slight increase in ridership; the new lanes remained mostly empty for most of the time. After this, Portland planners compiled a number of commuter surveys to investigate potential ridership and found, as shown in Figure 6, only 5% of Portlanders were willing to negotiate busy streets by bicycle, 7% were enthused and confident enough to try the on-street bike lanes, while approximately a third of the population were unwilling in any circumstances to commute by bike. The remaining 60%, however, fell into the 'interested but concerned' group. This majority group was defined as those who are interested in cycling but are worried about the difficulty, discomfort and danger. Using this data, planners shifted their strategy to better target the majority of citizens; working to eliminate the danger and stress of biking by installing bike boulevards and bike lanes that physically separated cyclists from cars. The strategy shift towards separated infrastructure showed a significant improvement, and commuting by bicycle in Portland more than doubled between 2000 and 2008.[53] So effective was this strategy adaptation that Portland cyclists make large detours to ride on protected bike

[53] Montgomery, *Happy City,* 212-3.

lanes and bike boulevards,[54] and cities across North America began referencing Portland's 'interested but concerned cyclist data in their endeavors to increase cycling.[55]

Cyclists are much more vulnerable on roads than drivers of automobiles, and planners and policymakers need to acknowledge and accommodate this through dedicated infrastructure if cycling modal share is to increase. Even though many studies have shown the effort that cyclists will make to ride on protected bike lanes and paths instead of with motor vehicle traffic, development of effective cycling infrastructure in North America lags nonetheless. Part of the reason has to do with bicycle enthusiasts themselves: in the 1970s enthusiasts joined forces with transportation planners to assert cyclists' right to the road through advocating the creed known as the 'vehicular cyclist'. This philosophy—which found its way into the American Federal Highway Administration's *Manual on Uniform Traffic Control Devices* and Ontario's *Highway Traffic Act*—demands respect for cyclists as equal travelers by directing cyclists to behave as if they were motor vehicles, applying all road rules to cars and bicycles one and the same. However, given the level of speed and protection, cyclists and automobile drivers are not the same. Treating bicycles as vehicles ultimately had the opposite effect than desired, reducing the accessibility of cycling and further marginalizing cycling modal shares on city streets. While appealing only to a small fraction of the general population (5% in Portland's study), this cycling philosophy fails to acknowledge cyclists' vulnerability—approximately half of people hit by cars moving 50km/h are killed, with mortality rates increasing sharply as speed increases.[56] Indeed, without the protection provided by a car frame, cyclists are not equal to drivers when it comes to safety, and policy and infrastructure should not treat them as such. Though the creed of vehicular cyclist ultimately diverts attention away from providing safe accommodations for the majority of interested cyclists, the mantra is however waning. Numbers of protected bike lanes and other cycling infrastructure in North America is on the rise since the turn of the century, and in approximate proportion, cycling rates are too. Illustrating this trend, Pucher, Buehler & Seinen conducted an aggregate cross-sectional study of North American cycling trends and policies. Their compiled results, illustrated in Figure 7 indicated "a positive correlation between cycling

[54] John Pucher, Ralph Buehler, Mark Seinen, "Bicycling Renaissance in North America," 466, 464.
[55] Take for example, page 23 of Chicago's *Streets for Cycling Plan 2020 (2013)*, or page 95 of Toronto's *Complete Streets Guidelines* (2017).
[56] Montgomery, *Happy City,* 192.

levels and the supply of bike paths and lanes, even after controlling for other explanatory factors such as city size, climate, topography, automobile ownership, income, and student population."[57] The lesson here is, in short: build safe and comfortable infrastructure and cyclists will come.

4.2 Bike Sharing: Impacts, Determinants & Typologies

4.2.1 Overall Benefits & Cycling Perception

Bike sharing as a mode of urban transportation is relatively new in North America. To date, it has had a relatively low impact when compared to other transportation modes, particularly the streetcar and the automobile. However, with its growing influence in many Canadian and American cities, a number of academics and researchers have sought to quantify its benefits and impacts. In a word, these benefits include greater transportation choice, increased amenity and transit accessibility, increased trip resilience and flexibility, a range of health benefits, travel time savings, and a reduction in transportation costs. Yet, many of these benefits are shared with the benefits of cycling on a private bicycle, making the impact of bike sharing to some degree difficult to differentiate. Nevertheless,

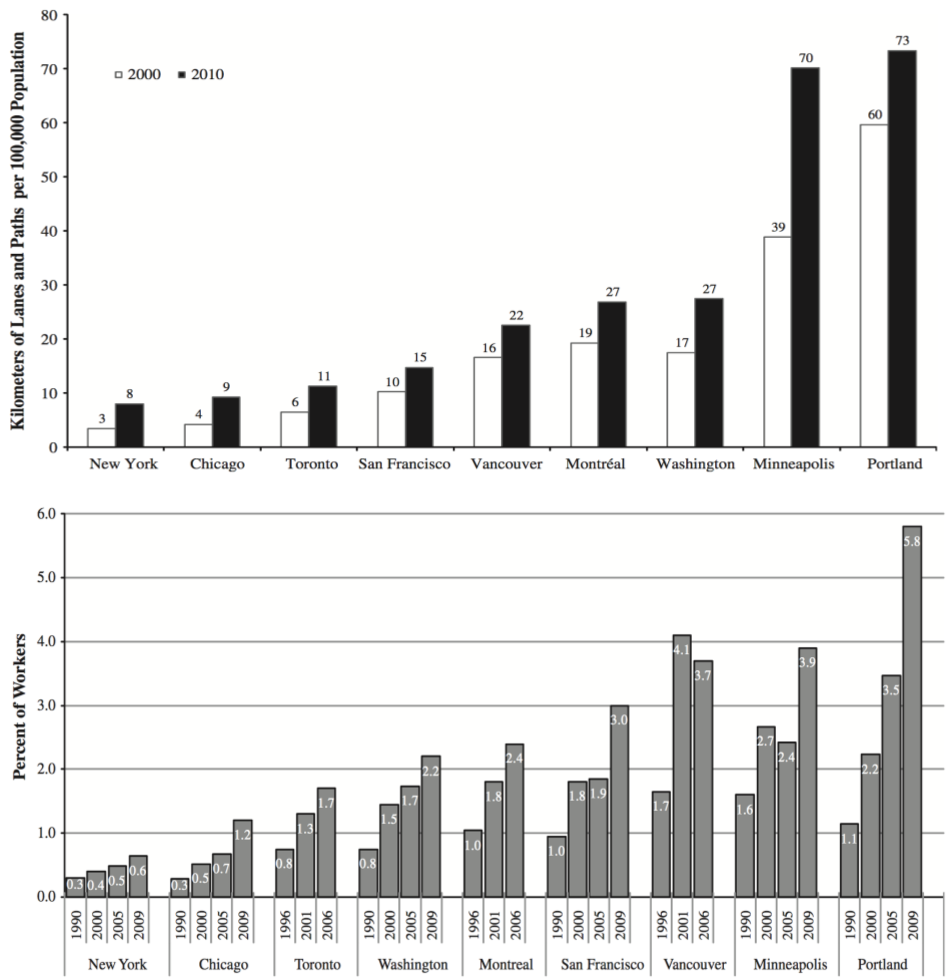

Figure 7. Rates of bike lanes(km/100,000) & percent (%) of Cyclist Commuters. Source: Pucher, Buehler & Seinen (2011).

[57] John Pucher, Ralph Buehler, Mark Seinen, "Bicycling Renaissance in North America," 464.

research has shown that where bike sharing does become distinct is its unique impact on increasing the public visibility of bicycles and normalizing the image of cyclists in casual clothing. As bike sharing programs significantly increase the number of visible bicycles in the public realm even when unused, and most bike share users ride with casual (or non-cyclist) clothing. Thus, perceptions of cycling as a viable everyday transportation choice become increasingly accepted as commonplace. Additional impacts include raising awareness of cyclists by drivers, and helping to lower the barrier of exploring urban cycling, all of which ultimately lend themselves to the encouragement of personal bicycle usage and increasing overall rates of cycling.[58]

4.2.2 Local Economic Impact

Cycling in general is also known to generate more localized economic activity. In Portland, for example, bicycling is accounts for an estimated $100 million in local economic activity annually.[59] There are also ways in which cycling generates net economic benefits that would not be present if the mode share of cycling was replaced by the automobile. For example, money otherwise being spent on automobile-related costs and gasoline is saved and, instead of siphoning to companies outside of the local or even provincial economy, has a high likelihood to be directed instead towards increased patronage of local businesses or other local economic activity.[60] Pertaining specifically to bike sharing programs, Ricci identified two studies which were seeking to quantify the local economic impacts of bike sharing. These two studies were consistent in suggesting that bike sharing is effective in contributing to the economic effects of cycling, particularly on a local- or neighbourhood-level. These studies suggested that "bike sharing [is] associated with consumer spending and some induced travel, and that cycling facilities can attract customers to nearby businesses."[61] In most cities with bike sharing programs, bike sharing stations are some of the most ubiquitous cycling facilities, and ones that are often trip start/end points, at least in terms of heightened aerobic activity. The expectation is

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[58] Cyrille Médard de Chardon, Geoffery Caruso, Isabelle Thomas, "Bicycle Sharing System 'Success' Determinants," *Transportation Research – Part A 100* (2017): 203; Elliott Fishman, Simon Washington & Narelle Haworth, "Bike Share's Impact on Car Use," 14.

[59] Joe Cortright, "Portland's Green Dividend," *CEO's for Cities* White Paper (2007), http://www.globalurban.org/CEOs%20for%20Cities%20Report%20on%20Portland%27s%20Green%20Dividend.pdf.

[60] Toronto Public Health, *Road to Health: Improving Walking and Cycling in Toronto* (2012), 19.

[61] Miriam Ricci, "Bike Sharing: Review of Evidence," 35.

that businesses that are adjacent to bike sharing stations or those in the immediately surrounding area benefit from increased patronage by bike sharing users. Furthermore, while there is a somewhat directly measurable effect of bike sharing stations on business patronage, the evidence for bike sharing enhancing the local economy suggests that the largest effects are cumulative ones, building on the multiple effects of bike sharing (i.e. bike sharing as cycling catalyst, effects on mode substitution) and are thus difficult to disentangle from the broader economic effects of cycling generally. This in part encourages further attention to the effects of BSSs on overall cycling rates to determine the cumulative economic impacts of such programs.

4.2.3 Ridership Determinants

In terms of bike sharing usage, research has shown that a number of factors play a significant role. These factors include trip purpose, station-residence proximity, network density, the relationship to the central business district (CBD) and built environment, and transit connectivity. A large-scale study was conducted in 2012 across four large North American bike sharing programs based in Washington DC, Montreal, Minneapolis-Saint Paul, and Toronto to identify the determinants of ridership, beginning with trip purpose. When users were asked about the purpose of their bike sharing trips, the most common response by a significant margin was for commuting purposes.[62] The study also determined, through interviews of BSS operators, that annual members were more likely to use the systems for commuting and regular, non-recreational journeys, whereas daily pass purchasers tended to use the BSS for more recreational trips.[63] A study of London's bike sharing program, Santander Cycles (formerly Barclay's Cycle Hire), had similar results, showing that work-related purposes dominated BBS trips.[64]

Another study looked at usage rates of the Montreal-based BIXI bike sharing program. The results suggested that proximity of residential addresses to docking stations has a powerful influence over the inclination of residents to use the BSS. In this study, almost 80% of respondents lived beyond 250m from a docking station, with 12.8% living within 250m from one docking station and 7.9% having more than one docking station within 250m." Out these respondents, Fishman et al. found that "for those living within 250m of a docking station, 14.3%

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[62] ibid., 157.
[63] Elliott Fishman, Simon Washington & Narelle Haworth, "Bike Share: A Synthesis of the Literature," *Transport Reviews 33:2* (2013): 157.
[64] Miriam Ricci, "Bike Sharing: Review of Evidence," 32.

had used BIXI, whereas only 6% of those living greater than 250m from a docking station used the service.[65] A different study of the BIXI Montreal system also found that people living within 250m of a docking station were over two times (+2x) as likely to become BSS users, while also citing socio-economic characteristics and travel behaviors as significant factors.[66] Related to the proximity relationship between station and residence is the effect BSS network density has on ridership. While studying how land-use and urban form impact BIXI Montreal's ridership, Faghih-Imani et al.'s analysis revealed how the number of stations has twenty-five times (25x) more of an impact on system usage than station capacity. This finding highlights that increasing the density of stations in a given area is far more likely to yield greater benefits to ridership than increasing the capacity (docking points) of a single station.[67] This serves to improve ridership catchment in any existing network service gap areas, and increase the frequency of available trip start/end points, making it easier for riders to find nearby bikes and brings docking points closer to many riders' final destinations. In this regard, the ultimate goal is to create a grid-like network of stations so that users are always within convenient walking distance to their next station.

In the same study, Faghih-Imani et al. also observed a consistent decrease in BIXI station usage as stations were placed farther from the CBD. This in part has to do with the network density factor just discussed, as Montreal's BSS network—like most bike sharing programs in North America—is densest in the city's core. However, the observed relationship with the central business district (CBD) also has to do with the CBD's built environment. This relationship can be explained by the degree to which a CBD is actively accessible. Active accessibility, defined

[65] Elliott Fishman, Simon Washington & Narelle Haworth, "Bike Share: A Synthesis of the Literature," 156.
[66] Miriam Ricci, "Bike Sharing: A Review of Evidence," 31.
[67] Ahmadreza Faghih-Imani, et al., "How land-use and urban form impact bicycle flows: evidence from the bicycle-sharing system (BIXI) in Montreal." *Journal of Transport Geography 42* (2014): 311.

as “the ability of an individual to reach relevant activities by active travel alone,” measured multiple factors that are considered both implicit and explicit. Implicit factors include density and diversity; denser places have more facilities and opportunities nearby, and a place with a greater mix of land-uses facilitates access to a broader range of opportunities and facilities. Explicit factors include distance and route characteristics; the distance to the closest facility is an

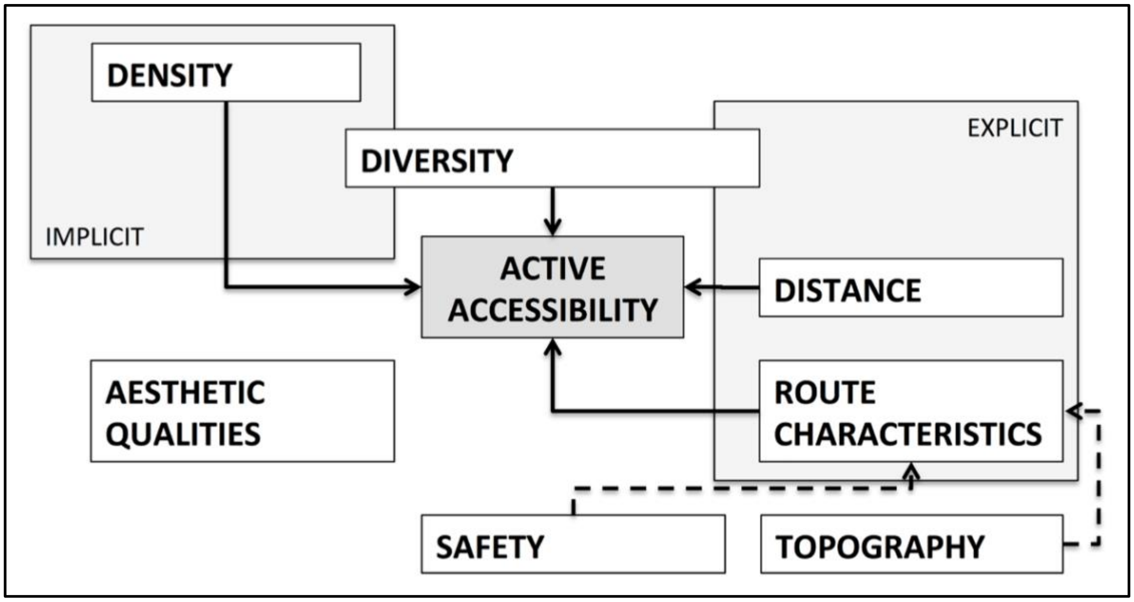

Figure 8. Measurements of Active Accessibility. Source: David S. Vale, Miguel Saraiva & Mauro Perera (2016): 212.

explicit measure of accessibility, while route characteristics such as street connectivity and infrastructure quality have a clear and explicit impact on accessibility.[68] The factors involved in the measurement of active accessibility are also illustrated in Figure 8. Faghih-Imani et al. and Ricci both recognize the positive impact a higher density and mixing of uses has on BSS usage; both have cited the number of uses, in terms of restaurants, universities, commercial uses, and overall job/population density as having a significant effect on station usage at various times throughout the day/week. The presence of nearby metro stations was also shown to be a factor in the usage of BIXI stations.[69] Ultimately, along with the CBD’s higher bike sharing network density and the associated user convenience, bike sharing’s relationship with the CBD is further explained by its built environment characteristics—bike sharing station arrival and departure

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[68] David S. Vale, Miguel Saraiva & Mauro Perera, “Active accessibility: A review of operational measures of walking and cycling accessibility.” *Journal of Transport and Land Use*, Vol. 9, No. 1 (2016): 212-3.
[69] Ahmadreza Faghih-Imani, et al. “How land-use and urban form impact bicycle flows,” 311; Miriam Ricci, “Bike Sharing: Review of Evidence,” 32.

rates decrease corresponding to decreasing population and job densities, deeper zoning segregations, and diminished connection opportunities to efficient transit.

Of course, as with all active transportation, bike sharing ridership is impacted by weather. In a study of Toronto's *Bike Share Toronto* system (one of the few systems operating year-round and exposed to significant winter weather), El-Assi, Mahmoud and Habib found a positive correlation between bike share activity and increased temperature. In their data, bike share ridership was at its highest when the perceived temperature was between 20 to 30 degrees Celsius. Lower temperature ranges of 0 to 10 and 10 to 20 degrees were also positively correlated with bike share activity in comparison to the base level of less than 0 degrees. The authors noted this data as evidence for systems remaining operational in the late fall and early spring periods. However, bike share ridership was also negatively correlated with precipitation, snow on ground and humidity as such provide unfavourable weather conditions for outdoors physical activity as the risk of accidents or injury tend to be higher."[70] In regards to winter operations, Bike Share Toronto ridership did decrease, although it did not flatline. As weather got colder in their study, El-Assi, Mahmoud and Habib found that midday trips decreased significantly, while peak morning and peak evening trips only showed a slight decrease. The authors noted that this "may be attributed to the decline of casual use of the system while the registered members continued to use bike share to commute."[71] Their findings support additional findings of a study of Capital Bikeshare in Washington, D.C., which showed a correlation between reduced ridership and cold temperatures, rain, and high humidity levels. [72] Yet, while cold riding conditions certainly are a practical deterrent to bike share usage and cycling generally, this paper suggests that built environment characteristics are in fact a more significant determining factor for ridership than winter conditions. As an illustrative example, take the commuter cycling ridership for the City of Toronto, estimated at 1.7% in 2006 as shown in Figure 7 earlier in this paper. While this is not remarkable, what is significant is the ridership jump in Toronto's downtown core area, which is estimated at 17%, not even including non-

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[70] Wafic El-Assi, Mohamed Salah Mahmoud, & Khandker Nurul Habib, "Effects of Built Environment and Weather on Bike Sharing Demand: A Station Level Analysis of Commercial Bike Sharing in Toronto," *Transportation* 44 (2017): 603.
[71] Assi, Mahmoud, & Habib, "Effects of Built Environment and Weather," 597.
[72] ibid., 592.

commuting utilitarian or recreational trips.[73] Thus, the ridership levels for Toronto, when excluding more suburban auto-dependant areas, seem to suggest that favourable built environment characteristics are perhaps the most significant factors for determining cycling mode share, even more so than cold riding conditions.

4.2.4 Bike Share Type

While modern bike sharing programs have been on the rise globally since approximately 2005, bike sharing in North America experienced more rapid proliferation only recently, with a sharp growth in both bike sharing providers and cities adopting BSSs since 2015. Most programs today are based in one of three system typologies: station-based, smart bike, or low-cost dockless. The longest-standing and often most well-established systems are station-based platforms operating in public-private partnership (P3) contracts with cities. Bike sharing programs of this type include systems such as BIXI Montreal, Bike Share Toronto, Capital Bike Share (Washington D.C.), Divvy (Chicago) or Ford GoBike (San Francisco). Bike Share Toronto's bicycle is shown in Figure 9. These station-based systems are based off of a model typology initially conceived by the predecessors of what is today the Montreal-based Public Bike System Company (PBSC). Stations are typically modular in design, wirelessly networked and self-contained with docks and a kiosk powered by a solar panel.[74] In contrast to station-based BSS platforms, smart bike platforms allow for free-floating systems with the option of removing station docks, integrating their governance technologies into the bicycle itself, utilizing global positioning systems (GPS) and geo-fencing technology to track BSS bicycles relative to digitized system boundaries.[75] While some municipalities still opt for stations of some kind for organization and predictability,

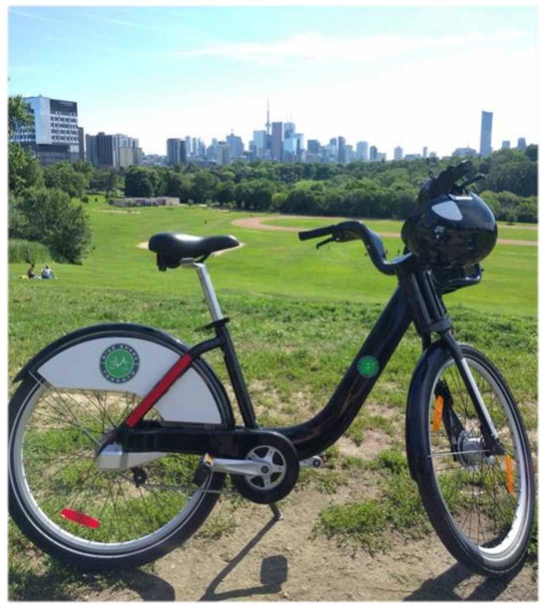

Figure 9. Bike Share Toronto bicycle in Riverdale Park, Toronto. Source: Hays (2017).

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[73] ibid., 590.

[74] Transport Canada, *Bike Sharing Guide*. Prepared by Gris Orange Consultant, 2009: 22.

[75] Susan Shaheen & Nelson Chan, "Mobility and the Sharing Economy: Potential to Facilitate the First- and Last-Mile Public Transit Connections." *Built Environment 42:4* (2016): 579.

these bikes can nonetheless start and end trips in any location. A smart bike system in Berlin is shown in Figure 10. These systems can optionally include docking stations for user convenience and predictability, or prioritize flexibility relying exclusively on GPS for users to find bicycles. A more recent development in the bike sharing industry is the advent of low-cost bike sharing services, provided by private companies using venture capital funds. One such Canadian start-up company, DropBike, began operations in Toronto in summer 2017 and has since expanded their

Figure 10. NextBike Station in Berlin, Germany. Source: Hays (2018).

operations to Montreal and Kingston, with another project opening soon in Kelowna BC.[76] Low-cost dockless BSS further eliminate the governance technologies integrated into stations or smart bikes, relying instead on the functionality of users' smartphones via a downloadable app. These BSS platforms, their operating basis within municipalities, and examples of prominent providers are illustrated in Figure 11 on the following page.

[76] "Working with Cities," Dropbike, viewed 7 February 2018. Url: https://www.dropbike.co.

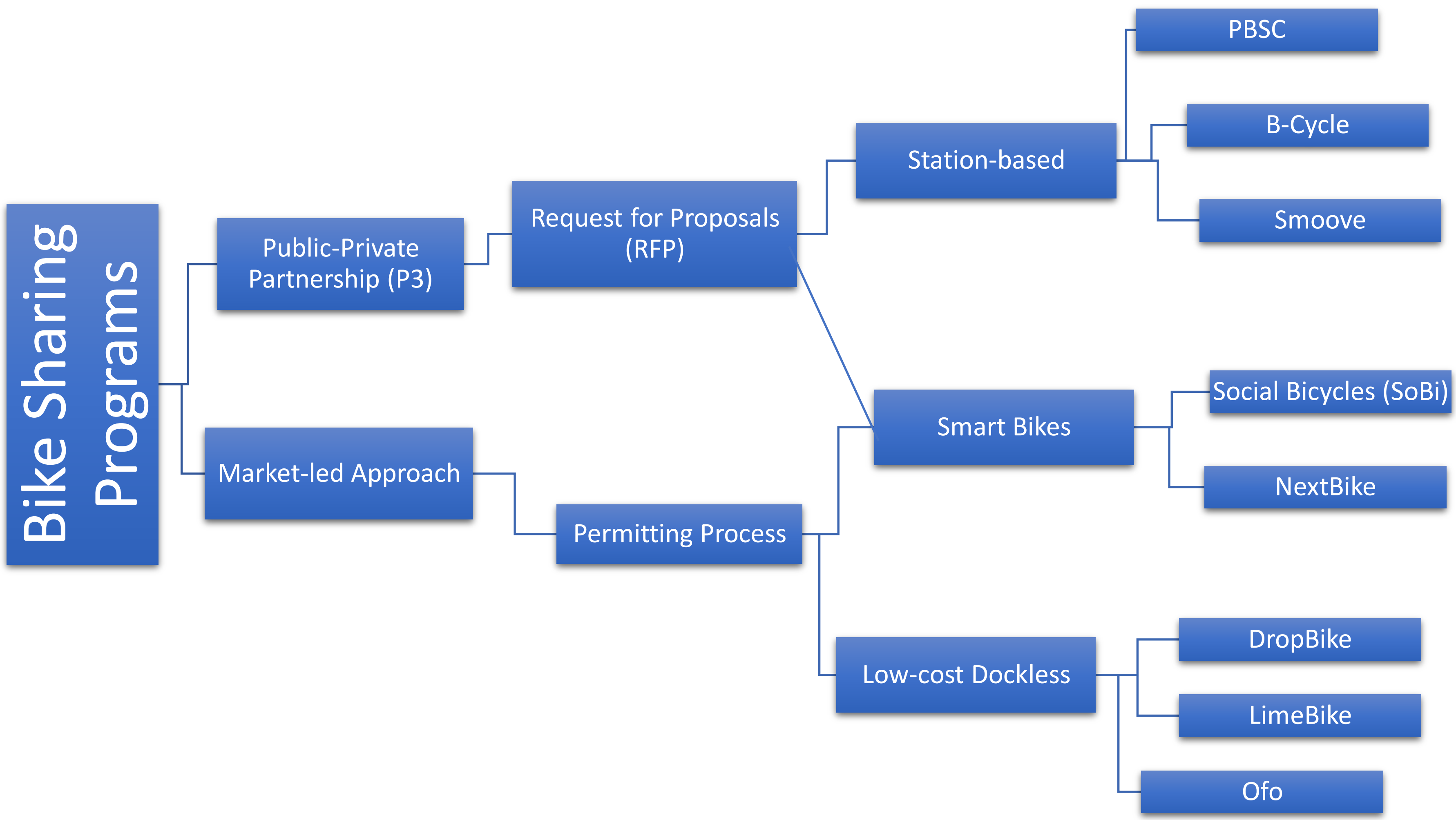

Figure 11. Bike Sharing Program Platforms.

In the case of station-based BSS platforms, Médard de Chardon et al. suggested station placement can be highly politicized, writing that stations are "a compromise between municipalities, politicians, system operators, local businesses, advertisers, profit potential, street and cycling networks, civil engineering and, finally, public interest."[77] The authors further note that the elimination of docking stations in smart bike platforms reduces costs considerably, and that operators of this type of BSS can benefit from this reduced cost as well as the benefits of increased station density via ease of deployment.[78] Other assessments of BSS platforms have further supported this, citing the costs of deployment and rebalancing efforts as the most significant disadvantages to station-based platforms.[79] However, Bike Share Toronto manager Sean Wheldrake argues that through the application of geo-fencing, smart bike platforms still function like a docked system, only with a virtually configured dock versus a material one.[80] BikePlus Project Manager Chris Slade found this same point with both smart bike and low-cost dockless platforms in the UK as well. While the case is already clear for geo-fenced smart bikes, even for low-cost dockless many municipalities have begun devising regulations to manage the orderliness of dockless bikes in the public right-of-way (RoW). Additionally, Slade explains "you'll probably see it come back around to a more formal version of encouraging people to leave their bikes in specific places because in some ways that helps operators redistribute their bikes better rather than just have their bikes everywhere." Hence, in a somewhat roundabout way, as dockless programs grow and municipalities increase regulations, low-cost dockless platforms also begin to operate in a similar way to docked programs with specific parking spots, only with somewhat less certainty.[81]

Yet, without the certainty and rigid user requirements associated with a fixed station network, the logistics of managing dockless systems become more complex and onerous for operators retrieving bikes for maintenance, repairs or redistribution.[82] This point is further exacerbated in the case of the more recent low-cost dockless platforms, whose ability to offer low-cost rates to

[77] Cyrille Médard de Chardon, Geoffrey Caruso, Isabelle Thomas, "'Success' Determinants," 205.
[78] ibid., 212.
[79] On Bike Share. "Bike Share Deployment Types: A Comparative Guide." White Paper (2018), 4.
[80] Sean Wheldrake, interview by Scott Hays, 29 November 2017, audio, 39:56.
[81] Chris Slade, interview by Scott Hays, 1 November 2017. Audio, 1:19:47.
[82] Transport Canada, *Bike Sharing Guide*, 23.

users is due at least in part to the lack of on-board governance technology and the low cost of the bicycles themselves. The previously mentioned reliance on user smartphone functionality to track bicycles in these platforms limits tracking to ride-time only, and as a result any interactions with the bicycle in between sign-outs goes untracked. This aspect, as well as the lack of controls or incentives for users to leave bicycles in convenient or accessible locations for future riders reflects the two biggest disadvantages to low-cost dockless systems: locations can be inconvenient and unpredictable, and bikes can be vulnerable to malicious actions, vandalism and theft.[83] As BikePlus's Chris Slade explained, "Previously, [challenges have] been to do with financial cost—that's changed. Now it's shifting to allocating street space and maintaining standards so that we don't have rogue operators . . . in the sense that they don't maintain their bikes well enough and their unsafe, and two, they're leaving their bikes in a manner that isn't causing danger to the public."[84] In the UK, this has led to the work of Chris Slade's organization, BikePlus, which assists in regulating low-cost dockless bike share providers. "We have an accreditation system that we've launched where we manage standards by essentially awarding a badge of accreditation to operators who we've vetted and [determined] they meet certain standards around how they park the bikes, their business standards, they're approach to social equity, and their approach to maintenance. So, it's almost an instrument of self-regulation, but it doesn't hold any standing law."[85] While this regulation appears to be a market response to a gap in formal state-led regulation and permitting, where attempts at regulation are dependent on the willingness of such operators to participate, in the UK as well as other places in Europe Slade says the experience has been somewhat positive in that the operators want to be self-regulating. Notwithstanding the caveat of a new operator "just coming and dumping two—three thousand bikes in a city," Slade says that the operators want to be self-regulating "because they realize they have to work with the cities to make their schemes work, and they realize that there

[83] On Bike Share. "Bike Share Deployment Types: A Comparative Guide." White Paper (2018), 4.
[84] Chris Slade, interview.
[85] Chris Slade, interview.

probably isn't enough space for all of them [in one location] for their model to function and work well"[86] Slade notes examples from the UK and Italy where, through accreditation processes agreed upon by the operators, a structured regulatory framework to the market-led low-cost dockless approach was achieved to benefit users, providers and municipalities alike.[87] Many cities in Italy maintain a number of dockless systems, which appear to integrate into the city in a cooperative fashion such as MoBike in Florence, seen in Figure 12.

Figure 12. MoBike staging area at the Central Station, Florence, Italy. Source: Hays (2018).

While the experience in Europe to low-cost dockless has seen some positive outcomes, the experience in North America has meanwhile not been as positive. While proliferation of low-cost dockless platforms has been rapid in North America within the last 2-3 years, some city officials and organizations are voicing concerns. Bike Share Toronto manager Sean Wheldrake suggested that low-cost dockless providers "are basically there not to provide a service to people but to make money for the companies."[88] This is echoed by SFMTA's Heath Maddox in San Francisco's experiences with low-cost dockless. "Our experience with [low-cost dockless bike sharing] has been less [than] positive. The first company to try and operate in San Francisco was BlueGoGo, and they were kind of the most aggressive that came in here early and made a mess of things. We kicked them out and they exited North America and now I think their CEO has run off with $100M worth of public money . . . the [dockless] development has been problematic."[89] Moreover, an official statement released by the National Association of City Transportation

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[86] ibid.
[87] ibid.
[88] Sean Wheldrake, interview.
[89] Heath Maddox, interview by Scott Hays, 21 November 2017, Audio, 55:56.

Officials (NACTO) stands in contrast to statements made by companies such as DropBike, claiming these companies operate without coordination with municipal officials, and with a disregard for transportation planning and municipal needs. Citing "poor quality and often unsafe" bicycles, NACTO's statement directly calls into question a number of aspects of these "rogue bike share companies," namely equipment quality; regard of public space and cyclist infrastructure; willingness for municipal collaboration; and their commitment to safety, quality of service, maintenance, and support for the public.[90] Moreover, an independent investigation of the status of low-cost dockless bike services in Seattle and the Washington DC area found 12% of bikes with major defects, compromising safe use.[91] Following the release of NACTO's official statement however, DropBike, the most prominent low-cost dockless BSS in the Canadian market, has since secured operating approval from city council in both Kingston ON and Kelowna BC, indicating some degree of interest from and coordination with Canadian municipalities.[92] As the most recent newcomer to the bike sharing world, it remains uncertain as to whether or not low-cost dockless BSS will successfully assimilate into the larger North American bike sharing industry and become a potential contender for meeting broader regional transportation system goals.

While outside the scope of this paper, an critical debate also exists around P3s that ties into broader debates around public transit, public vs. private ownership and the social structures of cities. Promoting a movement towards free transit and arguing against P3s and other neoliberal policies, Stefan Kipfer wrote that public transit is not only deeply connected to the physical form of cities, but is also "profoundly shaped by the deeper social structures of imperial capitalism."[93] Among these social structures is the internal contradiction clearly represented in transit P3s, which is the private delivery, operation, and thus commodification of public services. With the privatized land use intensification that follows, this privatized transit delivery process creates development pressures that depend on increased profitability and threaten less profitable uses.

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[90] Alexander Engel, "Rogue Bike Share Providers Raise Concerns for Cities: Coordination between cities and operators is key for successful systems," *National Association of City Transportation Officials (NACTO)*, 13 April 2017.
[91] Angie Schmitt, "Is the Dockless Bike-Share Revolution a Mirage?" *Streetsblog USA*, 7 February 2018.
[92] Farnia Fekri, "Press Release: Dropbike partners with City of Kingston to launch first dockless bike sharing service in a Canadian city." *Dropbike*, 26 June 2017; Frances Bula, "New bike-sharing systems are leaving the clutter of racks behind." *The Globe and Mail*, 30 January 2018.
[93] Stefan Kipfer, "Free Transit and Beyond," *The Bullet*, 3 December 2012, https://socialistproject.ca/2012/12/b738/.

By pushing lower-income jobs and housing away from transit infrastructure and into the suburbs, the land use implications of P3s have the potential to generate 'forced mobility' and "recreate the very centrifugal pressures that keep transit-hostile sprawl alive."[94] Indeed, Kipfer argued that the P3 approach to transit, which sees transit simply as a means to accelerate the circulation of goods and people, does not do enough to challenge car society. Kipfer wrote:

> "It accepts the deeper conditions that reproduce auto-dependency in the region: land-rent driven and private property-oriented urban development and a hollowed out public sector which depends on such development to raise property taxes. Indeed, through Metrolinx, this position now using regional transit as a Trojan horse to absorb the TTC and privatize what is left of the state's public transit planning capacity. Like the radical pro-car position, it is silent on the social relations of domination and exploitation that are woven into existing transportation practices."

Based in Lefebvre's idea of the 'right to the city', Kipfer argues that a free transit revolution is needed in order to create a new form of city building based on use-values and democracy rather than profit and private property, and truly public spaces that bring people together rather than entrench segregation and serve only the needs of certain class groups.[95]

4.2.5 International Examples of Transit-Integrated Bike Sharing

Just as the current state of low-cost dockless bike sharing platforms is more advanced in Europe than in North America, Europeans have more experience in terms of transit-integrated bike sharing systems as well. A number of European examples exist where rail-transit integration was the starting point. The Dutch bike sharing system Openbaar Vervoer-fiets (OV-fiets), or 'public transit bike' in English, is a first/last mile program implemented in 2001 by passenger railway operator Nederlandse Spoorwegen (NS). Designed as a transit-integrated program from its inception, the objectives of the program's implementation were: a) to acquire new train riders, b) encourage more trips by current train riders, and c) expand train station catchment area.[96] Through deploying bike sharing stations in and around train stations and offering a single-card payment system integrated with rail transit, results of the system found that "upwards of 10% of program participants shifted car trips to train-bicycle combined trips; meanwhile, transit-bicycle

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94 Kipfer, "Free Transit and Beyond."
95 ibid.
96 Natalie Villwock-Witte & Lottee van Grol, "Case Study of Transit-Bicycle Integration: Openbaar Vervoer-fiets (Public Transport-Bike) (OV Fiets)," *Transportation Research Record: Journal of the Transportation Research Board* 2534 (2015): 12.

users increased from 30% of riders to 50% of riders."[97] A similar program in Germany, the Call-a-bike service, was also developed in 2001 by the national passenger rail operator Deutsche Bahn (DB) specifically to facilitate access and egress to/from train stations.[98] Since then, DB's bike sharing programs have grown to become heavily used large-scale systems in a number of cities, such as Hamburg as shown in Figure 13. Aside from locating the bicycles at train stations, DB also offers rail customers financial incentives to use Call-a-Bike, discounting membership and usage fees for monthly train pass holders.[99] The program was developed alongside the Nation's largest car-sharing service, DB's Flinkster, and has recently been further integrated into third party mobility as a service (MaaS) applications such as Qixxit and Moovel, which feature seamless trip planning and semi-packaged payment options between transportation modes.[100]

Figure 13. DB bike sharing bikes corralled in Hamburg to support a city-wide festival. Source: Hays (2018).

In the North America, examples of transit-integrated BSSs are far less. One of the closest comparisons to such integration is LA's Metro Bike Share program. As a project directed partially by the Los Angeles County transportation authority, station operation coordinates internally with transit, and riders can use the same tap card between public bicycles and numerous forms of transit; although the back-end payment systems of Metro Transit and Metro Bike Share are still managed separately.

[97] ibid., 14.
[98] Transport Canada, *Bike Sharing Guide*, 59.
[99] ibid., 14.
[100] Maria Kamargianni et al. "A Critical Review of New Mobility Services for Urban Transport," *Transportation Research Procedia 14* (2016): 3299.

4.2.6 Program Models, Objectives, and Performance Measurements

A number of analysists have noted the ambiguity of many bike sharing programs' goals and objectives. While it is slowly improving, defining the objectives of BSSs continues to be a shortfall for many programs. Although acknowledging bike sharing's numerous benefits, Médard de Chardon et al. argued that between these benefits and an apparent lack of clear goals, determining "that an individual BSS is successful is challenging and the comparison of multiple systems [is] arduous."[101] While a multi-system comparison may be difficult not necessarily due to a categorical lack of goals, but perhaps due instead to multiple and varying objectives uniquely determined by each program, Médard de Chardon et al. nonetheless recognize the metric *number of trips per bike per day* (TBD) as a sufficient standard measure of performance.[102]

Using the standard metric TBD can be effective at measuring a BSS's general public uptake and assessing a system's capacity needs, particularly when considering cases involving city official's concerns over low-cost dockless companies' lack of transparency over ridership, and "neglected bikes littering streets."[103] However, using a standard performance metric of TBD as a measure of overall BSS success is problematic in capturing alternative goals to bike sharing, such as social inclusivity, transportation mode substitution or equitable access to transport. An example of this can be found in Madison, Wisconsin. The city's B-Cycle BSS has added public tricycles to their network to provide options for people who might lack the balance for a standard bicycle, while also offering greater storage capacity.[104] Aside from the additional cost of including these tricycles, their lower ridership evidently affects the overall system's TBD. Indeed, the use of a

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[101] Cyrille Médard de Chardon, Geoffrey Caruso, Isabelle Thomas, "'Success' Determinants," 203.
[102] ibid., 203.
[103] Angie Schmitt, "Is the Dockless Bike-Share Revolution a Mirage?" *Streetsblog USA*, 7 February 2018.
[104] Federal Transit Administration, *Manual on Pedestrian and Bicycle Connections to Transit*, prepared by Transportation Research & Education Center (TREC), Portland State University (2017), 77. Url: https://www.transit.dot.gov/sites/fta.dot.gov/files/docs/research-innovation/64496/ftareportno0111.pdf.

standardized TBD metric for comparing multiple bike sharing programs runs the risk of glazing over the policy objectives of individual programs. For example, this metric can disproportionately depict programs with goals other than maximizing financial performance or ridership in a negative manner. Consideration of the organizational structures of North American bike sharing programs depicted in Figure 14 can shed light on the various—and sometimes divergent—goals of bike sharing, and how a standard performance metric may not be appropriate in measuring program a program's effectiveness in achieving its policy goals.

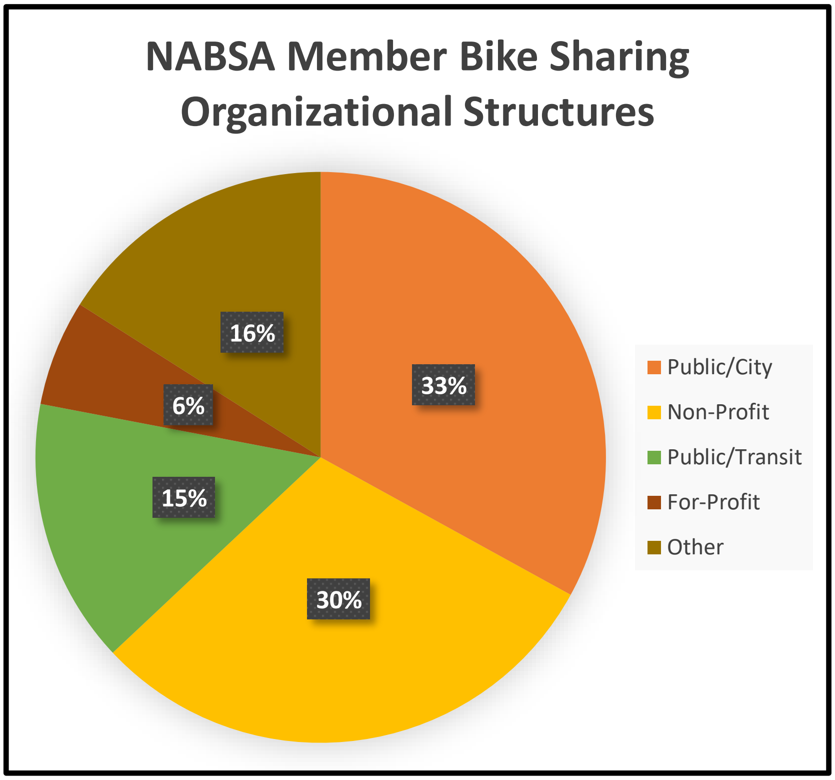

Figure 14. North American Bike Share Association (NABSA) 2016 Annual Survey

SFMTA senior transportation planner Heath Maddox described how ridership thresholds based on TBD that inform the appropriateness of bike sharing programs for any particular area really depends on policy goals and objectives for bike share program.[105] For example, using a standard TBD metric, non-profit programs within Médard de Chardon et al.'s sample ranked within the bottom third of performance rankings. While this can be the result of a number of factors (i.e. reduced access to capital for system promotion, less support from municipal actors, lack of commercial partnerships etc.), the authors note that optimizing a BSS towards maximizing performance "can marginalize social, economic, racial and gender equity outcomes," and thus programs prioritizing such outcomes are unfairly depicted in comparative assessments.[106] Ricci's review also mirrored this point, concluding "it remains problematic to reconcile the need to

[105] Heath Maddox, interview.
[106] Cyrille Médard de Chardon, Geoffrey Caruso, Isabelle Thomas, "'Success' Determinants," 211.

demonstrate financial and usage success on one hand, and social inclusivity on the other."[107] It therefore continues to be crucial for planners of bike sharing programs to define program objectives in connection to broader existing transportation plans and devise effective metrics for assessing each program's unique goals.

5. An Integrated Regional Approach to Bike Sharing

This paper argues that a transit-integrated regional approach to bike sharing can add to the seamless regional transit system that represents a core principle of the ST paradigm, while yielding significant benefits to local urban design and mobility as well. Such an approach can significantly enhance transit's competitiveness against the automobile, enabling transit-oriented designs of Urban Growth Centres that mitigate autocentric suburban sprawl. Employing this approach to GO Transit's upcoming Regional Express Rail (RER) and the Urban Growth Centres of the GGH can facilitate the complete communities desired in the Provincial *Growth Plan* to advance the GGH's polycentric urban network.

Incorporating bike sharing into regional transportation planning approaches provides the link that connects the regional with the local just as it connects the user from their door to the transit station. To realize its full potential in multimodal chains, bike sharing requires a high level of integration with the anchoring transit system in order to make it convenient and competitive against the personal automobile.[108] Simultaneously, a regional transit system that targets Urban Growth Centres to integrate bike sharing at the local level helps to facilitate Smart Growth goals, complete communities, New Urbanist design; and enhances the scope of transit-oriented development (TOD). Effective BSS-transit integration requires both transit fare and station integration, and is strongly compatible with newly emerging mobility as a service (MaaS) systems for seamlessness. A coordinated package of cycling infrastructure and BSSs can significantly increase cycling rates, contribute to station integration, and improve the cycling-transit interface generally. This package is also a crucial element to local design contributions, where it is argued BSSs should be considered as a fundamental design element to Urban Growth Centres in order to facilitate New Urbanist design and improved TOD. Ultimately, an integrated approach to bike sharing program implementation yields considerably higher benefits than bike

[107] Miriam Ricci, "Bike Sharing: Review of Evidence," 37.
[108] Federal Transit Administration, *Manual on Pedestrian and Bicycle Connections to Transit, 76.*

sharing operations in isolation, and can improve transit systems and urban design alike. This argument is what follows, starting with tis policy context in Ontario and brief discussion of potential locations for its early application.

5.1 Policy Context

Since the mid-2000s, the Province of Ontario has enacted a number of policies to make mitigating sprawl and improving regional transit a priority in the GGH region. In 2005, the Provincial Government of Ontario released the *Places to Grow* Act, followed in 2006 by the *Growth Plan for the Greater Golden Horseshoe* (referred to here as the *Growth Plan*) as the Act's legislative mechanism. Since its initial publication, the *Growth Plan* has undergone legislative review, and a revised edition was republished in 2017. The objective of the Act and its associated *Growth Plan* is to encourage greater transit-oriented development and to restrict the expansion of low-density development (i.e. sprawl). Reflecting these objectives, the *Growth Plan* called for increased density and intensification of existing built-up areas to accommodate the GGH region's growing population.[109]

The *Growth Plan's* intensification strategy employs Urban Growth Centres, intensification corridors and major transit station areas to guide urban development, and assigns minimum density requirements to each. In the City of Toronto, the minimum density requirements for Urban Growth Centres is 400 residents plus jobs per hectare, while a minimum of 150 to 200 residents plus jobs per hectare is assigned to the Urban Growth Centres of the surrounding municipalities in the GGH.[110] Necessary to the *Growth Plan's* intensification and increased density targets, the Plan's mandate emphasizes developing mixed-use, complete communities that are transit-supportive. Similar to Urban Growth Centres, the *Growth Plan* also identifies major transit station areas for minimum density requirements as well. These targets are set at 200 residents/jobs combined per hectare for stations served by subways, 160 residents/jobs combined for those served by rapid transit (LRT or BRT), and a minimum of 150 residents/jobs combined for stations served by GO Transit rail.[111] Recognizing transit as a first priority for intensification, the *Growth Plan* highlights the need for cycling- and pedestrian-friendly design to ensure

[109] Ontario Ministry of Municipal Affairs, *Growth Plan for the Greater Golden Horseshoe* (2017). Url: http://placestogrow.ca/images/pdfs/ggh2017/en/growth%20plan%20%282017%29.pdf.
[110] Ontario Ministry of Municipal Affairs, *Growth Plan*, 16-7.
[111] ibid., 17.

equitable connection to transit, homes, jobs and other amenities, while supporting climate change mitigation and adaptation objectives and improved public health outcomes.[112]

The development of these mixed-use, high-density growth centres aims to continue the transformation of the GGH region away from a monocentric metropolitan region, growing radially from downtown Toronto, to a polycentric network of developed city centres connected through intensified transit corridors. To ensure these constituent city centres properly aggregate into the functional and integral metropolitan region envisioned in *Places to Grow* and its associated *Growth Plan*, the Greater Toronto and Hamilton Area (GTHA)'s regional transportation authority Metrolinx established a regional transportation plan (RTP), devised initially in 2008 and revised in 2018, which was designed to vastly improve integration and connectivity of transit networks throughout the region.

Metrolinx's initial RTP in 2008 entitled *The Big Move: Transforming Transportation in the Greater Toronto and Hamilton Area* set long-term and capital-intensive regional transportation plans, the core of which focuses on a regional rapid transit network (RTN) "that operates seamlessly across the region . . . supported by comprehensive and robust local transit networks, cycling and pedestrian networks, transit-supportive land uses, and supporting policies and programs."[113] With the goal of connecting many Urban Growth Centres by express regional transit, the RTN set out to build off of the existing Go Rail network, electrifying the GO Rail corridors and bringing all-day, two-way express rail service operating in 15- minute intervals to most service areas.[114] This is project is significant both for the scope of work and for the improvement it will bring to the GGH. Research identified by Schiller, Bruun & Kenworthy has shown that rail systems have "the biggest positive systemic effect on urban systems. When cities are classed and analysed in the framework of strong rail, weak rail and no rail cities, it has been demonstrated that the more significant the rail system, the higher is the use of the transit system service, as well as the occurrence of walking and bicycling."[115] Revised in 2018 simply as the *2041 Regional Transportation Plan For the Greater Toronto & Hamilton Area*, the current RTP

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[112] Ontario Ministry of Municipal Affairs, *Growth Plan*, 12.
[113] Metrolinx, *The Big Move: Transforming Transportation in the Greater Toronto and Hamilton Area* (2008), 22.
[114] Metrolinx, *2041 Regional Transportation Plan for the Greater Toronto and Hamilton Area* (2018), 53-4. Url: http://www.metrolinx.com/en/docs/pdf/board_agenda/20180308/20180308_BoardMtg_Draft_Final_2041_RTP_EN.pdf.
[115] Schiller, Bruun & Kenworthy. *Sustainable Transportation*, 243.

puts even more emphasis on complete door-to-door travel experiences through planning for first- and last-mile connectivity, enhancing cycling through cycling networks and better urban design, and connecting people with high-order transit through shared mobility services.[116] As the complementing transportation plan to Ontario's strategic *Growth Plan*, Metrolinx's RTP represents the backbone for connecting Urban Growth centres and bringing local communities together across the region. These transit links to the region's Urban Growth Centres is shown in figure 9, with emphasis given to the area in which this paper identified as a potential application case.

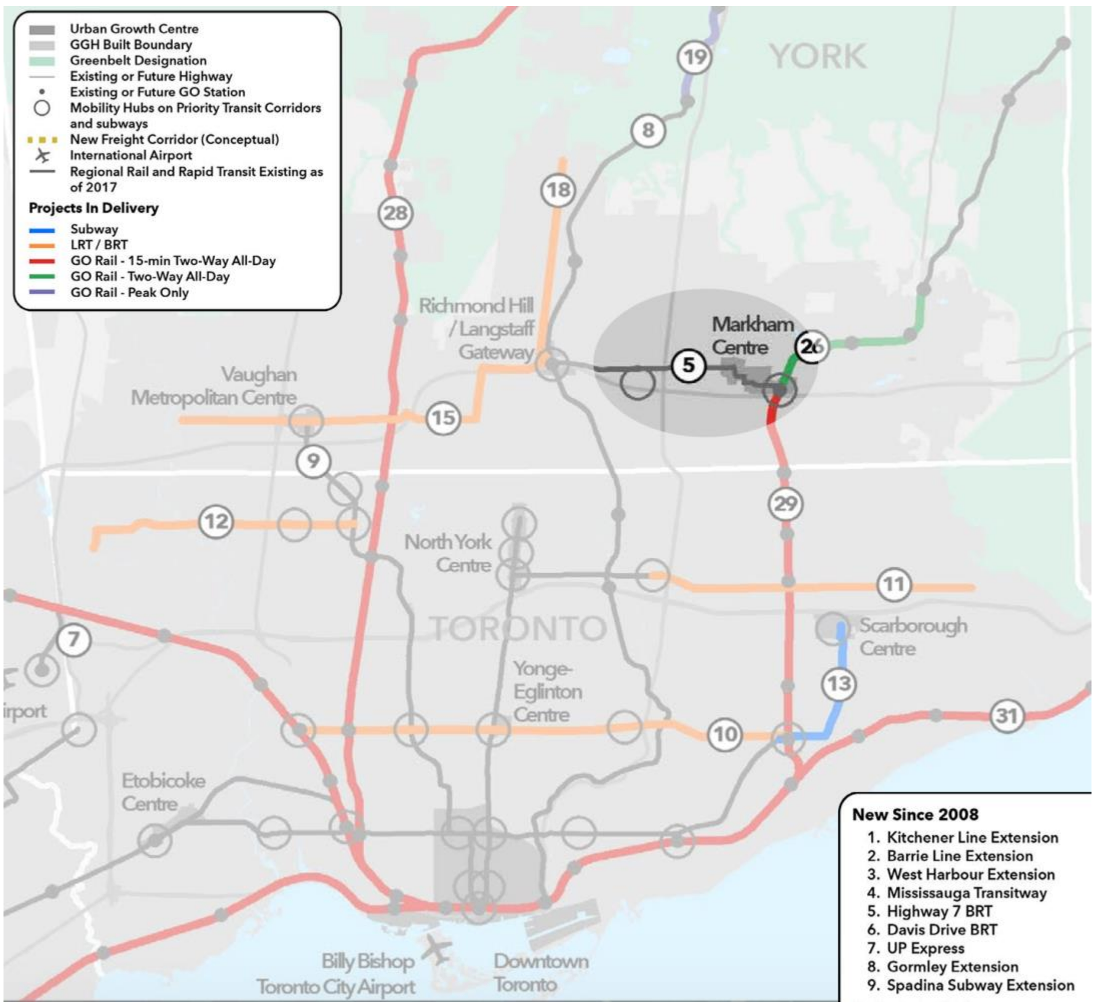

Figure 15. Urban Growth Centres connected via GO rail and Rapid Transit. Source: Metrolinx (2018).

[116] Metrolinx, *2041 Regional Transportation Plan, 43, 68-9, 82-3.*

5.2 Application

This paper proposes consideration of bike sharing programs as a fundamental component in the urban planning and design regional transit nodes within Urban Growth Centres. Considering the lens of bike sharing implementation in the urban planning and design process can serve to improve built environment outcomes for intensification, even in areas where BSS implementation is not immediately feasible. Since benefits to built environment outcomes is a goal of BSS application, and built environment has been shown to be a more significant determinant of ridership than winter conditions, BSSs in Urban Growth Centres are expected to operate year-round. Moreover, as transit integration is another goal and studies show that many Bike Share Toronto and other bike sharing users ride year-round for their commutes, it would be appropriate to provide the service regardless of weather to ensure users have the transit options that are desired. Depending on the current built environment and bike sharing program business model, some Urban Growth Centres may be deemed inadequate for BSS operations prior to intensification outcomes. Nevertheless, there are a number of suburban Growth Centres in the GGH region that could support immediate bike sharing implementation if coordinated with TOD intensification processes and integrated with the delivery of GO RER or other high-order transit. While the arguments and urban design treatments brought forward in this paper are generalized to all urban growth centres, a particular Growth Centre is identified for the purposes of an application example. As such, an applicable Urban Growth Centre for the potential implementation of bike sharing systems has been identified in Markham Centre, shown in Figure 15 as well as in Figure 16 with greater detail.

Markham Centre is identified for early BSS implementation in order to coordinate intensification and TOD with transit services and guide additional development in a manner that successfully maintains new urbanist and cycling-oriented designs. The reasons for Markham Centre's specific identification as an example for early BSS implementation are numerous. Firstly, the area maintains a high density of institutional 'anchors' within or surrounding Urban Growth Centre boundary, which serve as important focal points for trip generation. Specifically, the growth centre and surrounding area contain a high concentration of commercial, employment, recreational, as well as residential uses of both lower and higher densities. These include the Markham Pan Am Centre, Markville Mall, a new urbanist-style shopping and entertainment centre including a movie theatre and hotels, a number of both elementary and secondary schools, the nearby Seneca College, and a future York University campus.

Importantly, Markham Centre is also well-served by high-order transit. Unionville GO station is contained within the growth centre just east of the new urbanist-style centre, and Highway 7, the north delineator of the centre, is serviced by Viva bus rapid transit (BRT). This BRT corridor also connects to the Richmond Hill Centre, the proposed future site of a Yonge subway expansion station. Deploying bike sharing systems and cycling infrastructure in conjunction to these transit services not only assists in satisfying the objectives of the *Growth Plan* and RTP, including the revitalization and establishment of complete streets; it also encourages and facilitates mixed-use and expanded TOD development, provides door-to-door mobility connections for GO Rail and Viva BRT, and serves to increase cycling rates and car modal substitution in an intensifying suburban area.

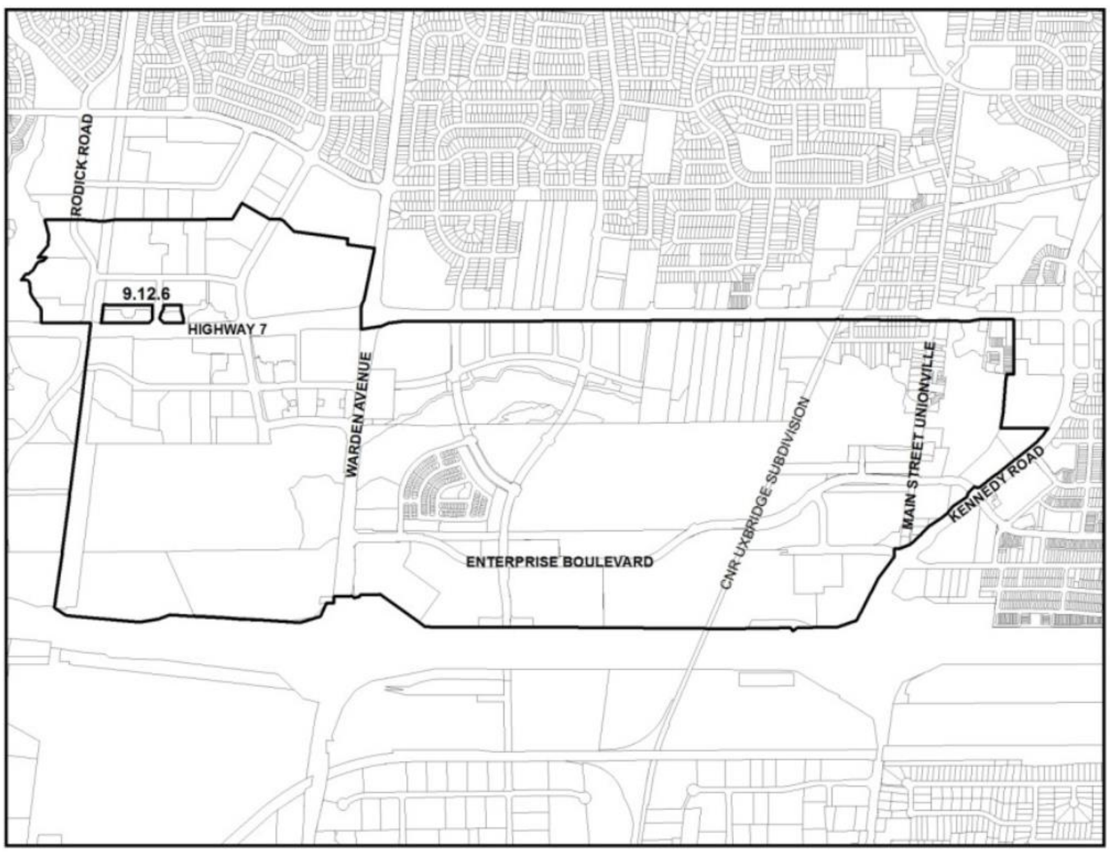

Figure 16. Markham Centre. Source: City of Markham Official Plan, 9-85 (2014).

Markham Centre has also been designated by Metrolinx as the location for a future Mobility Hub. Consisting of Unionville GO as well as the surrounding area, Markham's mobility hub is typical with an approximately 800m in radius that "serve a critical function in the regional transportation system as the origin, destination, or transfer point for a significant portion of trips." These areas are human-scaled, prioritize active transportation and transit, and contain "an intensive concentration of working, living, shopping and/or playing.[117] The elements of a mobility hub are detailed in Figure 17. The confluence of the factors outlined here makes Markham Centre a prime candidate as a suburban Growth Centre for implementation of bike sharing systems and supportive cycling infrastructure. In addition, a secondary area for expanding bike sharing system implementation can be identified in the Richmond Hill Centre/Langstaff Gateway Urban Growth Centre, connected to Markham Centre by the Viva BRT as previously mentioned. The close proximity of another Urban Growth Centre, served by high-order transit and connected to Markham Centre by BRT, further makes this location ideal for BSS implementation. It is logical for bike sharing programs to expand contiguously so as to "create a grid of stations" and avoid discontinuities that might impact users.[118] Hence, the close proximity of Markham Centre and Richmond Hill Centre/Langstaff Gateway make for an ideal area for expanding a BSS, using the Highway 7 BRT corridor as the anchor to join two BSS-serviced Urban Growth Centres. Eventually, this process could establish a larger BSS service area that can serve as the foundation for development of additional high-order transit to service the municipality and enable further TOD. It should once again be noted here that this paper provides arguments and urban design treatments that are generalized to Urban Growth Centres broadly, and that the specific identification of Markham Centre serves only as an example of an ideal suburban area for the application of these ideas.

[117] Metrolinx, *Mobility Hub Guidelines for the Greater Toronto and Hamilton Area* (2011), 4. Url: http://www.metrolinx.com/en/regionalplanning/mobilityhubs/01SectionsI-II.pdf.
[118] Heath Maddox, interview.

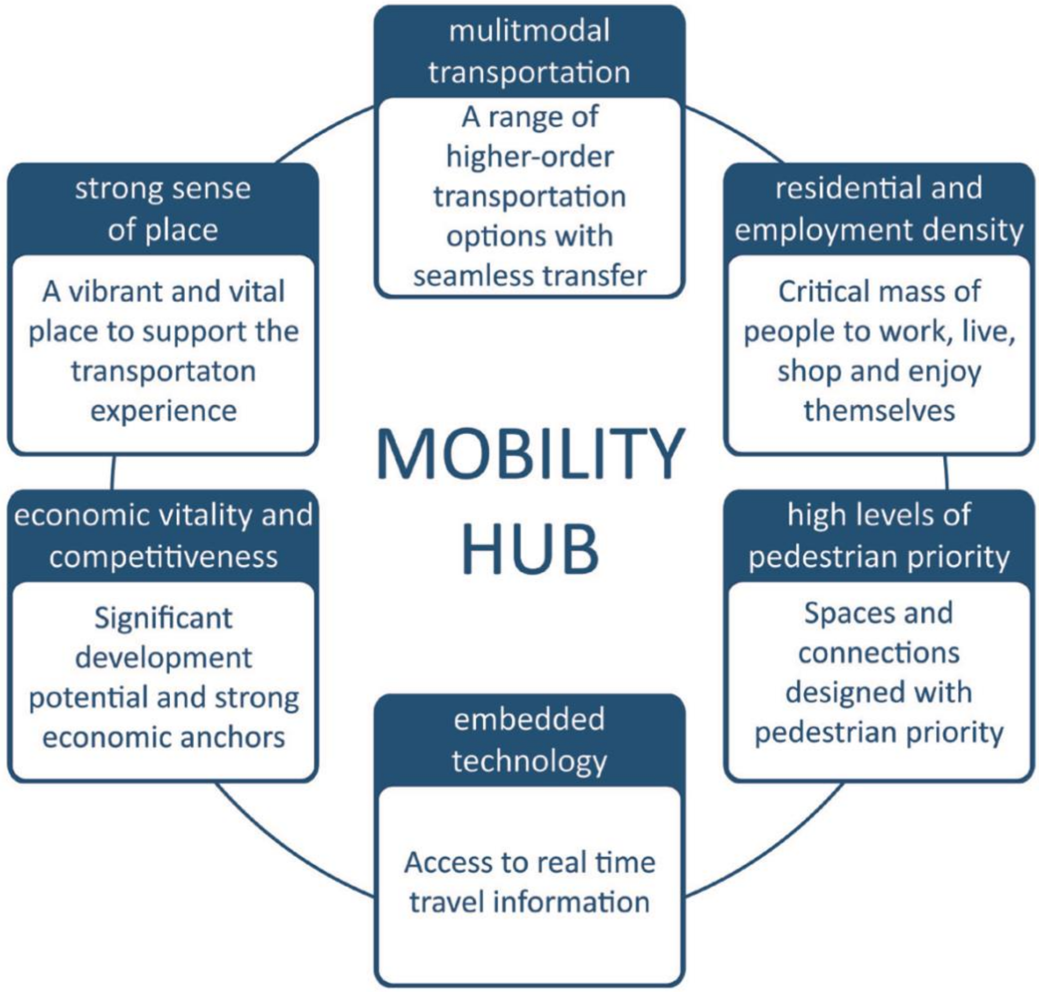

Figure 17. Mobility Hub Elements. Source: Metrolinx (2011).

5.3 Bike Sharing, Cycling Infrastructure & Induced Demand

While the previously discussed research into cycling infrastructure has clearly shown the latent demand for cycling, as well as the catalytic effect dedicated infrastructure can have on that latent demand; questions remain as to how bike sharing can play a similar role. The limited research into bike sharing concludes BSSs can increase overall cycling rates, but whether such programs target the 'interested but concerned' majority demographic remains a question. However, with the data available, this paper argues that bike sharing can considerably strengthen the demand inducing effects of cycling infrastructure if strategically linked to it.

5.3.1 Inducing Cycling Demand

Just as wide roads can induce demand for cars, dedicated cycling infrastructure can induce demand for bicycles. The phenomenon of induced demand is long documented by transportation experts yet as Duany, Speck and Lydon noted, it is routinely ignored in traffic engineering practice in North America—visible when traffic congestion leads engineers to widen roads and increase lanes.[119] Ironically, as shown in Figure 12, road capacity increases tend to have the opposite effect—ultimately increasing demand, and before not too long, creating more congestion. The phenomenon was confirmed in a study spanning 30 California counties between 1973 and 1990, which found that "for every 10% increase in metropolitan roadway capacity, vehicle-miles traveled increased 9% within 4 years' time."[120] Planners in some European cities have long acknowledged this, with cities like Amsterdam and Copenhagen dramatically reinventing the way city residents use their streets. As Montgomery wrote, "just as North American cities created more automobile traffic through decades of road building, Copenhagen has induced demand for other ways of moving, especially cycling, by making streets more

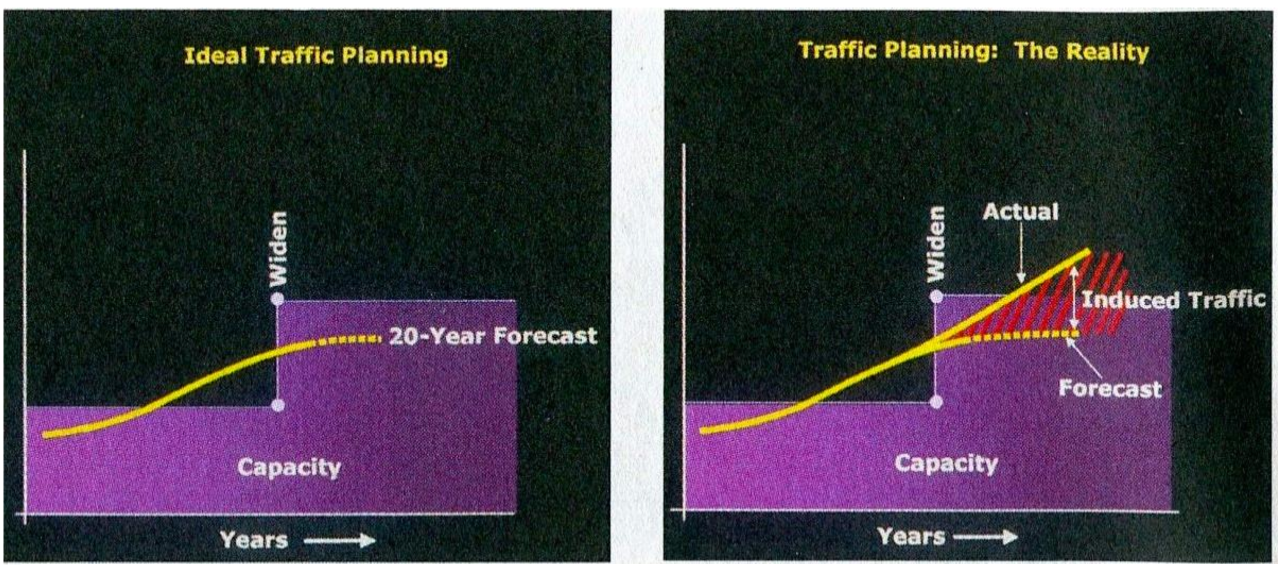

Figure 18. Induced Demand. Source: Duany, Speck & Lydon (2010).

complete."[121] Indeed, the same processes that induce automobile demand—increasing connectivity and capacity of dedicated infrastructure—can induce cycling demand as well.

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[119] Duany, Speck & Lydon, *The Smart Growth Manual*, 3.10.
[120] ibid., 3.10.
[121] Montgomery, *Happy City, 220.*

Although, while infrastructure has improved and expanded throughout North America since the turn of the century, still only 1.7% of workers in Toronto commuted by bicycle in 2009. When considering the entire GTHA, that number decreases to just 0.9%,[122] suggesting a significant degree of latent cycling potential still unrealized.

Depending on its application, bike sharing can prove to make a significant impact on catalyzing this latent demand. Yet, results are bound to be limited given the current spatial deployment of most systems. In terms of user demographics, analysis of current systems have compiled a "well established and broadly consistent body of evidence" that shows that the users of BSSs are by and large educated and employed white males who, most importantly, are "more likely to be already engaged in cycling independently of bike sharing."[123] However, this paper argues that the constrained spatial distribution of BSSs primarily within urban downtown areas and CBDs can be expected to skew the user demographics towards a similarly constrained demographic. Indeed, the limited availability of stations to the areas with most available ridership (CBDs in this case) also inadvertently tends to direct the system's utility towards a more homogenous group of users. Carrying forward, the expectation is that deployment of BSSs into a broader range of spatial and socioeconomic areas can increase the demographic range of users as well as the overall usage rates. However, it should be noted that further research is necessary here to confirm this expectation.

In spite of the standard user demographic model of BSSs, a significant body of evidence exists to suggest bike sharing can indeed create new cyclists. Experience from Paris, a city with relatively low cycling rates amongst European cities, shows that the introduction of their *Vélib* BSS sparked increases in cycling rates. With less than 2% of trips made by bicycle at the time the system was launched, *Vélib* quickly garnered a trips/bike/day (TBD) rate of 8-10, making it one of the most used systems in the world as of 2009.[124] Additionally, noting recent surveys of BSS users in London and Dublin, Ricci reported that 78% of London users started cycling or cycled more as a direct result of the BSS; while 68.4% of surveyed Dublin BSS users "claimed not to

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[122] Metrolinx, *Active Transportation Background Paper – Full Report: Technical Paper 1 to Support the Discussion Paper for the Next Regional Transportation Plan,* prepared by Steer Davies Gleave (2015), 55. Url: http://www.metrolinx.com/en/regionalplanning/rtp/technical/01_Active_Transportation_Report_EN.pdf.
[123] Miriam Ricci, "Bike Sharing: Review of Evidence," 30.
[124] Transport Canada, *Bike Sharing Guide,* 17.

have cycled for their current trip prior to the [system's] launch." More interesting still, another 63.4% of surveyed Dublin users who own their own private bicycle "said they purchased it as a result of using the scheme."[125] As this evidence seems to suggest, BSSs can indeed be an effective catalyst of both public and private bicycle uptake and increasing overall cycling rates. Furthermore, evidence of BSS usage in relation to cycling infrastructure can help to potentially triangulate the usage of BSSs to users of the 'interested but concerned' 60% demographic. A considerable body of evidence on this shows heightened rates of bike sharing station usage based on nearby cycling infrastructure. These studies, based on Washington D.C.'s Capital Bikeshare and Montreal's BIXI systems, show that even when controlling for population and retail opportunities around stations, a "statistically significant relationship between bike share activity and the presence of bike lanes exists."[126] This indeed suggests that bike sharing may already attract some 'interested but concerned' cyclists, and begins to suggest a more complex interrelationship between BSSs and cycling infrastructure for increasing cycling modal share.

5.3.2 Bike Sharing – Infrastructure Relationship

Promoting cycling by coordinating BSSs with cycling infrastructure can produce a sum of results greater than its individual parts. The available research on bike sharing has shown its propensity to reduce the barriers of urban cycling.[127] Inherent to their concept, bike sharing programs eliminate the burden of bicycle ownership (cost of bike purchase, maintenance, storage/parking, theft concerns etc.) while simultaneously making cycling more accessible; without any planning, users can simply walk up to a nearby station and relatively inexpensively take a bike and have access to the system for the day. Moreover, "convenience" in its broadest sense consistently emerges as a key motivating factor for bike sharing use,[128] as BSSs facilitate ease of one-way trips. Research also shows that BSSs also positively impact the perceptions of cycling, normalizing cycling an easy and effective means of everyday travel rather than a high-speed toy.

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[125] Miriam Ricci, "Bike Sharing: Review of Evidence," 32; Elliott Fishman, Simon Washington & Narelle Haworth, "Bike Share: A Synthesis of the Literature," 33.
[126] Fishman, Washington, Haworth, "Bike Share: A Synthesis of the Literature," 160; Ahmadreza Faghih-Imani, et al., "How land-use and urban form impact bicycle flows: evidence from the bicycle-sharing system (BIXI) in Montreal." *Journal of Transport Geography 42* (2014): 311; Cyrille Médard de Chardon, Geoffrey Caruso, Isabelle Thomas, "'Success' Determinants," 206.
[127] Cyrille Médard de Chardon, Geoffery Caruso, Isabelle Thomas, "Bicycle Sharing System 'Success' Determinants," 203.
[128] Miriam Ricci, "Bike Sharing: Review of Evidence," 31.

After researching BSSs in European cities, Transport Canada's *Bike Sharing Guide* suggests that the introduction of BSSs can "trigger the development of a non-recreational cycling culture, compelling local residents to see the bicycle in a new light as a viable mode of urban transportation."[129] Thus, by normalizing the image of cycling and reducing the barriers to cycling, BSSs can be understood as an effective cycling promotion initiative with a dualistic effect. As Braun et al. have found, cycling promotion initiatives prove more successful if they not only target cycling infrastructure improvements itself, but also the perceptions of that infrastructure and its adequacy. This suggests that combining the two can have a significant impact on cycling modal share.[130] Hence, it is argued that the combination of BSSs and dedicated cycling infrastructure can create a synergistic effect that increases the applicability of bike sharing outside of dense urban CBDs and induces demand from the latent 'interested but concerned' cyclists. In short, bike sharing can popularize cycling by making it easy and convenient for new cyclists to start biking, while protected infrastructure provides the level of comfort and security for novice and casual riders to enjoy their commutes and continue their riding activity.

5.3.3 Positive Feedback Loop

The effect that combining BSSs and protected cycling infrastructure can have on overall cycling rates can be understood as a positive feedback loop. Zahabi et al. found evidence of this in a 2016 Montreal-based study exploring the link between neighbourhood typologies, bicycle infrastructure and cycling rates. In this study, Zahabi et al. found a broad increase in the rate and likelihood of cycling, regardless of neighbourhood typology, over a 10-year period from 1998. With the likelihood increasing in 2003 and 2008 by 4% and 19% respectively, Zahabi et al. attributed this progressive change to attitudinal changes in the population resulting from a series of interventions to the built environment and cycling infrastructure within the same timeframe. Zahabi et al. estimated that the cycling infrastructure interventions initiated a positive feedback loop that popularized cycling in an accelerating fashion. Noting "many studies on the behavioral aspects of cycling [that] found a phenomenon of a positive feedback cycle which prevails in

[129] Transport Canada, *Bike Sharing Guide*, 17.
[130] Lindsay M. Braun et al. "Short-term Planning and Policy Interventions to Promote Cycling in Urban Centres: Findings from a Commute Mode Choice Analysis in Barcelona, Spain." *Transportation Research – Part A 89* (2016): 177.

many large cities," Zahabi et al. referred to a feedback loop where the expansion and improvement of cycling infrastructure serves to increase safety and visibility for cyclists, generating an increase in bike modal share, which then leads back to further necessity and political capital for additional cycling infrastructure improvements. Although BIXI began operations in Montreal the year following this study period and thus data on BIXI's additional impact is not available, it is proposed here that the introduction of bike sharing can and would facilitate a further acceleration of this effect.

Consideration should be given to both BSSs and protected cycling infrastructure not as just complementary initiatives, but rather as a single synergistic and coordinated package. Some research has identified quality cycling infrastructure as an important complementary, or in some cases, determining factor that sustains BSS use. In turn, bike sharing can further promote and normalize the image and practice of cycling, contributing to increasing overall cycling levels, both public and private.[131] By combining efforts of both bike sharing and cycling infrastructure, bike sharing programs can viably be applied outside of CBD areas, latent cycling demand can be substantially induced, and new urbanist and smart growth objectives can be facilitated in areas previously thought to be impracticable. Due to the described synergistic relationship between BSSs and protected cycling infrastructure—serving as a cycling 'gateway' for new and novice riders, mutually supportive usage rates, their shared effects on the normalization and perceived/actual safety of cycling—a coordinated package of protected cycling infrastructure and BSSs could serve to enhance and increase the demand inducing effect on the majority of 'interested but concerned' potential cyclists and the positive feedback loop seen in many cities' cycling initiatives. Figure 19 illustrates the potential feedback cycle of coordinating cycling infrastructure improvements with BSS deployment.

[131] Miriam Ricci, "Bike Sharing: Review of Evidence," 36.

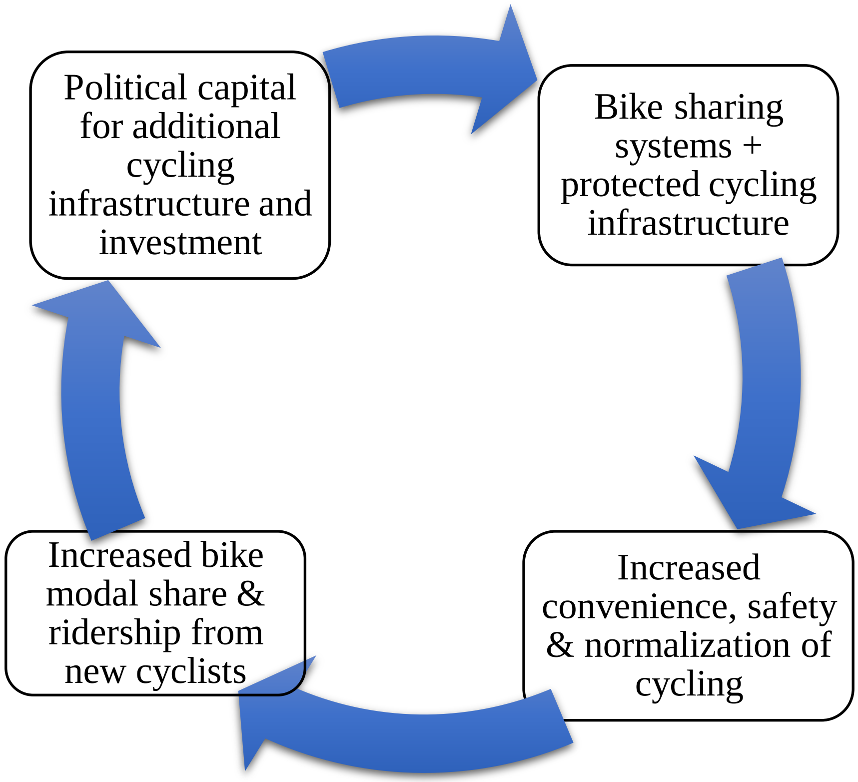

Figure 19. Bike Sharing - Protected Infrastructure Positive Feedback Loop

By inducing demand with such a coordinated package, the benefits to cycling rates and safety run both ways: cities with the highest bike modal shares will also have the safest cycling—safer cycling encourages more cycling, and more cycling encourages greater safety.[132] This approach represents a powerful launching point initiative for increasing both bike sharing ridership as well as overall cycling rates. If deployed in suburban growth centers, this strategy can prove to generate strong modal shift from automobiles, reducing vehicle kilometers travelled (VKT), and combat autocentric development by facilitating more demand for compact development and human-scaled design in the streetscape and public realm.

5.4 Integrating Bike Sharing with Regional Transit

Integrating BSSs into the upcoming GO RER network can foster complete mobility that outperforms the automobile and advances the ST paradigm. While linking more traditional forms of transit (e.g. streetcar-subway interfaces, bus-rail interfaces, etc.) has long been commonly

[132] John Pucher, Ralph Buehler, Mark Seinen, "Bicycling Renaissance in North America? An Update and Re-appraisal of Cycling Trends and Policies." *Transportation Research – Part A 45* (2011): 462-3.

accepted practice, integrating flexible mobility such as bike sharing or car sharing is a concept that is only recently catching on in North America. In July of 2018, the Toronto Transit Commission (TTC) board passed a motion to explore giving the TTC broader powers that would transform the TTC into a mobility management agency, integrating the management of traditional transit with taxis, bike sharing, car sharing, parking, and road pricing.[133] However, transportation experts like University of Toronto associate professor of geography and planning Matti Siemiatycki argue that the value of mobility management in the GTHA would be in a regional approach, not a municipally based one. In a CBC News interview, Siemiatycki explained, “regional is the approach where we’ve been moving to get the best service quality . . . The user doesn’t care who is providing the service. They want a consolidated, seamless service that allows them to pay with one fare mechanism and travel seamlessly across an entire region.”[134] As argued in this paper, a regional approach to BSS-transit integration makes the most impact, and is what aligns most effectively with current provincial policy goals in regards to growth, urban planning and transportation. Without a regional approach to transit management, “turf issues” between multiple transit agencies further entrench the barriers to integration as the ridership potential between municipal boundaries lags and communities remain disjointed.[135] Similar issues can be seen in the San Francisco Bay Area, where a regional approach to bike sharing was taken. Without a regionally-based mobility management approach to coordinate the BSS amongst the five cities it spans throughout the Bay Area, “trying to coordinate with the different municipalities was very challenging,” says SFMTA senior transportation planner Heath Maddox.[136]

Given the immediate and future provincial policy goals, particular attention should be given to regional mobility management and the ST paradigm. Achieving these policy goals can be done by integrating BSS with RER and other high order fixed-route transit within Mobility Hubs and Urban Growth Centres. In dissuading car use, mobility management considers the total door-to-door transportation needs of trip, where first/last mile solutions seek to efficiently fill gaps at the

[133] Ryan Patrick Jones, “TTC board approves proposal to expand control over transportation I Toronto,” *CBC News,* 10 July 2018, http://www.cbc.ca/news/canada/toronto/ttc-board-to-hear-proposal-to-expand-control-over-transportation-in-toronto-1.4739934.
[134] Jones, “TTC board approves proposal.”
[135] ibid.
[136] Heath Maddox, interview.

beginning and end of such trips. While integration for regional transit reasonably starts with fare integration and cycling-supportive station design, the emerging concept of mobility as a service (MaaS) shows potential as an end-goal in connecting flexible and shared mobility services with fixed-route transit to a level not yet seen. The potential of bike sharing programs to serve as a first/last mile solution to RER and other fixed-route transit, the ability and requirements for integrating services, and the extent to which MaaS can serve as the basis of such integration, will be discussed here.

5.4.1 First/Last Mile Solution to Regional Transit

Bike sharing has the potential to enhance and expand the catchment of transit services if deployed in the right locations and in an effectively integrated manner. In particular, BSSs in the GGH region can serve in multimodal trips as a flexible first/last mile solution for fixed-route rapid transit systems such as BRT, LRT, subways and regional rail.[137] Defined by Metrolinx as the challenge of connecting people from transit stations/hubs/stops to their home, workplace or other major destination and vice versa, the first/last mile problem today increasingly looks to innovative solutions that eliminate the requirement of car use.[138] Fulfilling this desire, BSSs can increase access and ridership to RER while eliminating the necessity of the automobile for station access, the long-established model of GO commuter train stations.

Many BSS riders already use the service as part of a multimodal chain, connecting to another mode of transit for the next section of a larger trip. Thus, while not completely seamless in its interfacing with transit, BSSs are already performing a first/last mile role. In the case of San Francisco, SFMTA senior transportation planner Heath Maddox stated, “certainly people are using [bike share] for first/last mile. Our highest used locations are at or near regional transit.”[139] Moreover, in 2010 Murphy found that 55% of Dublin BSS users integrate it as part of a trip chain; this rate is similar for BSSs in Beijing and Shanghai, with 58.4% and 55% of respondents combining bike sharing with transit respectively. Melbourne’s BSS also found a strong relationship between station usage and proximity to train stations, and in Washington D.C. over

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137 Transport Canada, *Bike Sharing Guide*, 14.
138 Metrolinx, *2041 Regional Transportation Plan for the Greater Toronto and Hamilton Area* (2018): 107. Url: http://www.metrolinx.com/en/docs/pdf/board_agenda/20180308/20180308_BoardMtg_Draft_Final_2041_RTP_EN.pdf.
139 Heath Maddox, interview.

half of respondents to a Capital Bikeshare member survey stated they used the BSS to access the train system.[140] Here in Toronto, Bike Share Toronto manager Sean Wheldrake explained that "a lot of people use bike share with transit . . . it could be 10% of our users are going intermodal, it could be 25%." While noting that much more research is required on the subject, Wheldrake suggested that the multimodal usage of bike sharing in Toronto is because of the high transit usage rates in Toronto; transit integration is not indicative to bike sharing per se, but rather to the built form and transportation characteristics of the city.[141]

5.4.2 Variations of BSS Impact on Automobile & Transit Use

The impacts bike sharing has on automobile and transit use vary from city to city as well as city core to city periphery. The relevant research shows firstly, how the usage of BSSs changes relative to the built form of the area that the system serves; and secondly, the variable nature of bike sharing's impact on other transportation modes based on the location and purpose of its deployment. As Fishman et al. noted in their study on BSS's impact on car use, "a substantial proportion of trips currently taken on bike share in the cities included in this study are substituting for public transit and walking, which is [also] consistent with a study of the Montreal bike share program known a BIXI."[142] Similarly, Shaheen et al. conducted a two-part study of public bike sharing programs in North America (2012 and 2014) investigating the impact of bike sharing on transportation modes. The results are summarized in Figure 20 below.

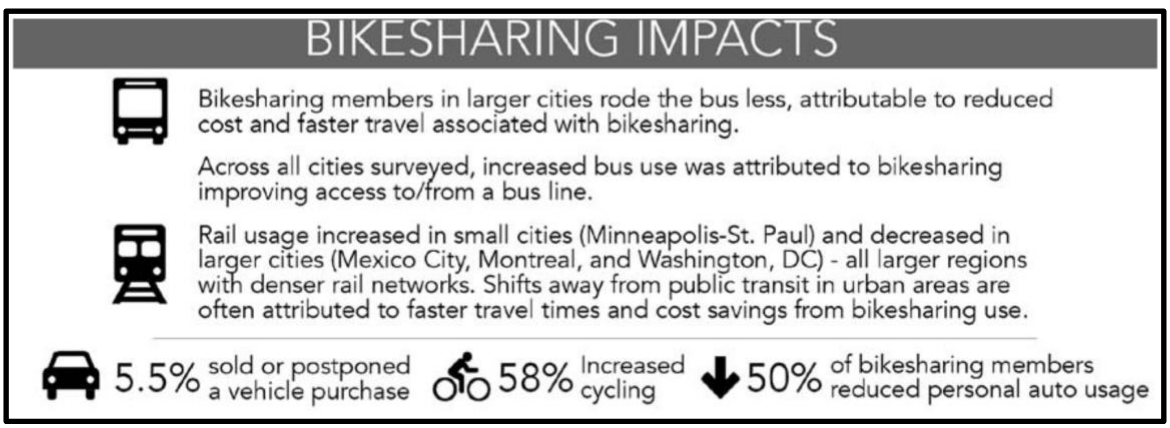

Figure 20. Source: Susan Shaheen & Nelson Chan (2016).

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[140] Elliott Fishman, Simon Washington & Narelle Haworth, "Bike Share: A Synthesis of the Literature," *Transport Reviews 33:2* (2013): 156-8.
[141] Sean Wheldrake, interview.
[142] Elliott Fishman, Simon Washington & Narelle Haworth, "Bike Share's Impact on Car Use: Evidence from the United States, Great Britain, and Australia." *Transport Research – Part D 31* (2014): 15.

As illustrated, the results suggest that BSSs in larger cities reduce overall bus use and overcrowding, while in smaller cities bus line access is improved. Moreover, half of all BSS users reported reducing their personal automobile use, and respondents of larger cities reported that rail usage decreased due to faster travel speeds and cost savings, while respondents of smaller cities reported an increase in rail usage, such as Minneapolis-St. Paul.[143] While these figures lack a desired level of detail in regards to the type of transit described (no distinction within 'rail' between subway and regional rail, nor in 'bus' between mixed-traffic, regional or rapid transit bus services) as well as the travel behaviours between the city's urban core and suburban periphery, it nonetheless shows the positive effects of bike sharing, and is indicative of the possible relationship between built form and the variance of BSS use.

Moreover, studies have shown that deploying BSSs in peripheral suburban environments generates more automobile substitution, and cooperates more diretly with other transit than in an urban core. Shown in Figure 21, numerous BSS surveys from Europe, Australia and North America have shown that more bike sharing mode substitution comes from other low-carbon modes such as walking and public transit than from cars.

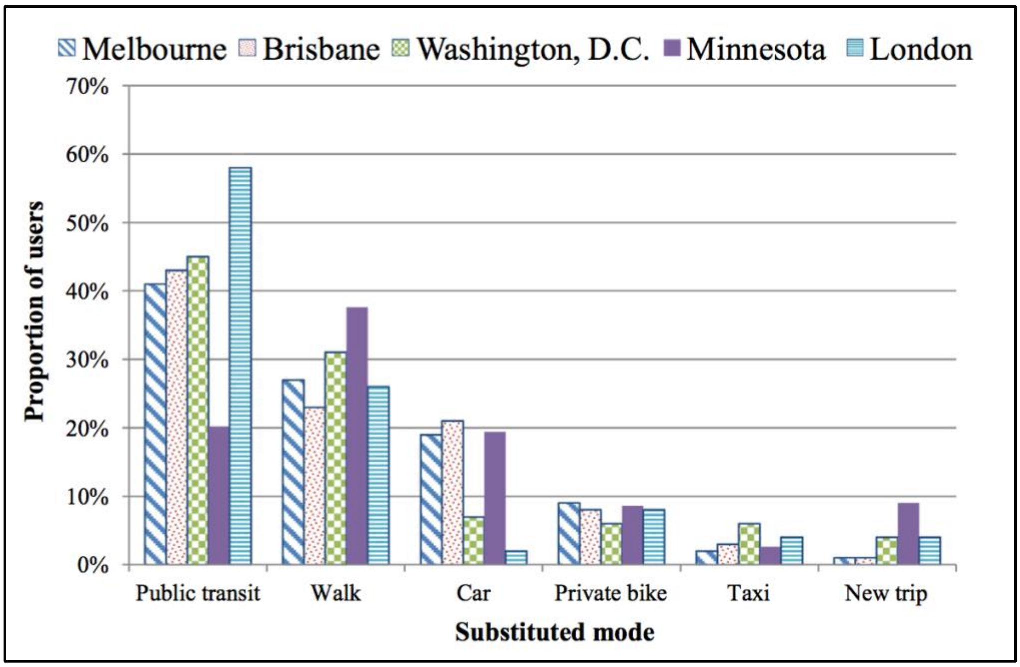

Figure 21. Bike sharing mode substitution in selected cities. Source: Fishman et al. (2014).

However, conforming with arguments in the previous section, researchers attribute this to the "relatively compact space in which schemes operate." Indeed, the scale of mode substitution from walking and transit is a consequence of the predominant deployment of BSSs in cities'

[143] Susan Shaheen & Nelson Chan, "Mobility and the Sharing Economy," 580.

urban cores and CBDs, where programs focus on readily obtainable ridership due to a higher density and land-use mix and more frequent short-distance trips. In these areas, transit is already well established and neighbourhoods are typically more walkable and cycle-friendly. Hence, compared to more autocentric suburban areas, the car already holds a lower modal share due to competition from more effective transit and more walkable and complete neighbourhoods. This is further correlated by data from cities with relatively higher car modal share than others, which show that BSS users "exhibited a higher car mode substitution rate than BSS users in cities with an already low car modal share."[144] This once again suggests a strong relationship between BSS use and built form. London, UK for example exhibited a very low substitution rate with the car, but a very high substitution rate from public transit. Yet, Fishman et al. suggested that for a city such as London, "car use is already rather inconvenient and many people who could choose an alternative have, making it more difficult for bike share to attract new trips from car users."[145] More importantly, as Bike Share Toronto manager Sean Wheldrake explained, the strategic goal of the BSS in London was to reduce transit overcrowding in the first place.[146] In serving intensification processes, bike sharing could therefore be plausibly expected to have a higher car mode substitution rate in suburban areas that are transitioning from a more auto-oriented build form with less effective transit.

Ricci also found more BSS-transit cooperation within suburban areas compared to urban cores in another bike sharing user survey. This survey geocoded home and work locations of respondents in order to associate commute origins and destinations to travel behavior responses. The results showed that behavioral shifts away from public transit in response to bike sharing were "found to be most prominent in core urban environments characterized by high population density, whilst shifts towards public transport were most common in lower density areas on the urban periphery." Paring this with the fact that survey participants' most common response to increasing bus/rail use as a result of bike sharing was due to "better access both to and from a bus/rail line," Ricci concluded that "for users living in areas with less available/frequent public transit options, bike sharing can generate public transport journeys by acting as a first or last mile

[144] Miriam Ricci, "Bike Sharing: Review of Evidence," 32, 33.
[145] Elliot Fishman, Simon Washington & Narelle Haworth, "Bike Share's Impact on Car Use," 17.
[146] Sean Wheldrake, interview.

connection."[147] This is further supported by the US FTA, which concluded that in areas of lower density outside of city cores, "bike share users are inclined to use the service to access transit," whereas bike sharing in city centers serve as an alternative to transit. Consequently, through higher rates of direct substitution from automobiles in suburban regions, compounded with the potential to serve as a first/last mile solution to other transit services, evidence has shown that bike sharing can in fact be a more effective mechanism for sustainable transportation mode substitution when deployed in suburban areas than in urban cores. While the ability to substitute transit with bike sharing in urban cores gives users valuable transportation options and redundancy, the increased transit access in more suburban, autocentric areas can make BSSs an effective tool for expanding the reach and viability of transit where it is needed most.[148] Key to this outcome however, is the inclusion of bike sharing in transportation policy and planning to maximize its potential and direct it within a coordinated effort to transform suburban areas and the means of which its inhabitants get around their neighbourhoods and the broader urban region.

5.4.3 Integrating Bike Sharing with Transportation Policy and Planning

Integrated policymaking and planning is a key factor in the creation of a ST paradigm.[149] Likewise, including bike sharing programs into transportation planning and polices is needed in order to utilize the full potential that BSSs can add to transportation networks. Griffin and Sener have noted that while efforts towards integrating BSSs with transportation planning has been increasing since 2010, the initial establishment of bicycle sharing programs in North America "was on an opportunistic basis rather than as a prescriptive solution towards defined transportation needs."[150] Many programs developed with available public and private funding but without a strategic connection to broader transportation planning objectives and thus lack a level of integration with transit services as seen in some European systems. However, while bike sharing's relationship with transit is the result of a complex interrelationship amongst various factors, its application can serve a variety of policy goals if integrated with transit policies. Ricci noted the ability of BSSs to both complement and substitute for public transit has a significant policy implication and utility for managing public transit demand, "for example reducing

[147] Miriam Ricci, "Bike Sharing: Review of Evidence," 33.
[148] Federal Transit Administration, *Manual on Pedestrian and Bicycle Connections to Transit, 73.*
[149] Schiller, Bruun & Kenworthy, *Sustainable Transportation,* 223.
[150] Greg Phillip Griffin & Ipek Nese Sener. "Planning for Bike Share Connectivity to Rail Transit," *Journal of Public Transportation 19:2* (2016): 4.

overcrowding on some services, promoting use of others or helping integrate different public transport modes."[151] In the case of overcrowded transit systems, bike sharing can be a cost-effective augmentation to a suite of transport options. For example, Bike Share Toronto manager Sean Wheldrake explained that paying a million dollars to expand a BBS can have a similar effect on decreasing overcrowding on a particular route or subway line as paying another ten million to increase capacity for the subway system.[152] SFMTA transportation planner Heath Maddox has a similar view: "in San Francisco, our transit system is severely overburdened. So even if [bike share] is stealing from municipal buses or rail, that's not a problem—that's welcome. It's not like they're stealing revenue, they're creating more capacity . . . and it gives people another option, maybe a faster one."[153] Yet, in order to employ bike sharing's utility in public transit demand management, consideration to BSSs needs to be given in the policy and planning systems of transportation networks. Without it, the mutually beneficial integration of BSSs and high order fixed-route transit such as express rail will continue to be problematic.

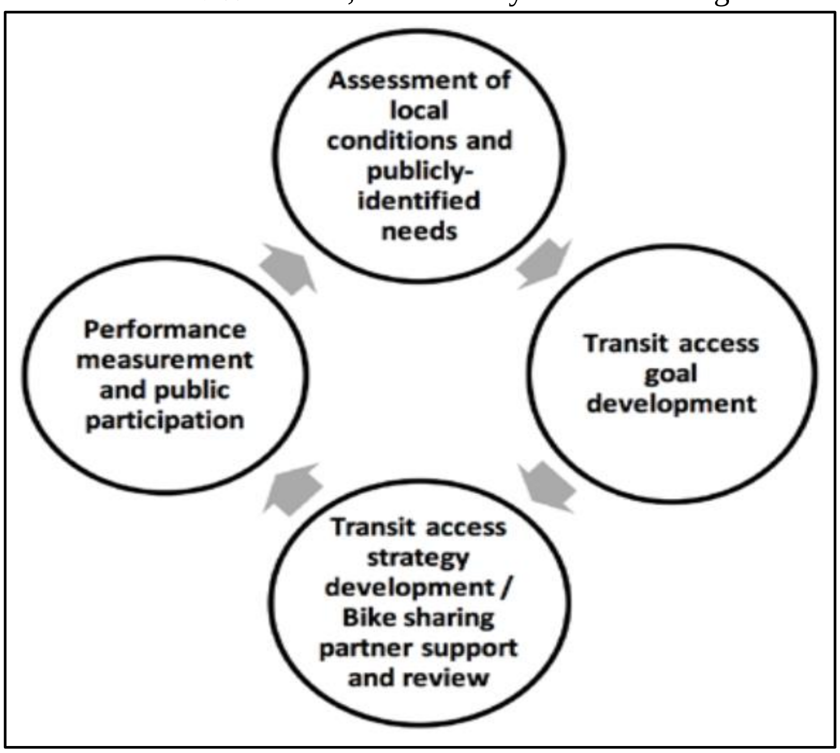

Figure 22. Source: Griffin & Sener (2016): 14.
"The process starts with a simultaneous assessment of needs from both perspectives. A cross-disciplinary team then formulates goals to address the transit access issues found in the first step. Specific strategies then need to be developed, again leaning heavily on a partnership with the local bike sharing provider to work proactively towards the shared goals."

Since most modern bike sharing programs in North America were opportunistic in their origins, the task of reconciling BSS's with larger transportation planning processes can be difficult. However, the maturation of the bike sharing industry is leading to increased recognition of

[151] Miriam Ricci, "Bike Sharing: Review of Evidence," 37.
[152] Sean Wheldrake, interview.
[153] Heath Maddox, interview.

BSSs as an effective addition to transit and so planning integration might soon be less difficult. This was evident in a 2016 study by Griffin and Sener evaluating local intermodal plan goals and their relationship with BSSs in Austin, Texas and Chicago, Illinois. Through interviews, Griffin and Sener found that while BSS planners considered proximity and frequency of transit as a factor in their initial suitability analysis, and their station siting process included efforts at major railway stops, "neither system planner reported any existing guidance that could help them develop the bike share plan in an integrated manner with rail transit."[154] Since then, however, Griffin and Sener noted the City of Austin surprisingly as one of the first American cities to explicitly include specific bike sharing expansion goals amongst its municipal plans—the city's 2014 Bicycle Master Plan states the objective of "expanding Austin's bike share system from 40 stations to 100 stations by 2016 and to 300 stations by 2017."[155] With increasing recognition and inclusion in local policy directives, the hope is that bike sharing will become an early consideration in transit planning rather than an afterthought. Ultimately however, the fragmented approaches to bike sharing in these two cities and the variance of planning policies between them demonstrated, firstly, a rapid advancement in the role of bike sharing; and secondly, "a lack of planning between modes, perhaps constrained by funding silos and bureaucracy."[156] As a result Griffin and Sener recommended a framework for integrating bike sharing and transit planning goals, illustrate in Figure 22. Using this as an example, including bike sharing programs in transportation planning and policy can set the foundation for bike sharing to play a larger role in transportation networks, the impacts of which can contribute towards significant change in the design of cities, centres and neighbourhoods.

5.4.4 Bike Sharing Potential with Rail in Multimodal Chains

The available data and literature on bike sharing programs show that BSSs are most effective for connecting users to rail services, such as GO Transit's anticipated regional express rail (RER), subways and LRTs. While BSSs that serve as feeder role for express and rail transit may be replacing other feeder services such as bus routes in city cores,[157] as stated earlier it nevertheless offers valuable redundancy to users and fills the accessibility gap for users in between the typical

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[154] Greg Phillip Griffin & Ipek Nese Sener. "Planning for Bike Share Connectivity," 13.
[155] ibid., 12.
[156] ibid., 13.
[157] Julie Bachand-Marleau, Jacob Larsen & Ahmed M. El-Geneidy, "Much-Anticipated Marriage of Cycling and Transit: How will it Work?" *Transportation Research Record 2247* (2011): 116.

catchment areas of walking and feeder buses. Meanwhile, evidence shows that express rail services maintain a higher coordination potential with bike sharing. Specifically, research has shown that rail transit systems provide a particularly salient opportunity of a mutually beneficial relationship with bike sharing, "where the shortcoming of rail's high speed and distance between stations can be served well with bike sharing to solve the well-researched last-mile problem."[158] Numerous cities across the globe have demonstrated the particular relationship between BSSs

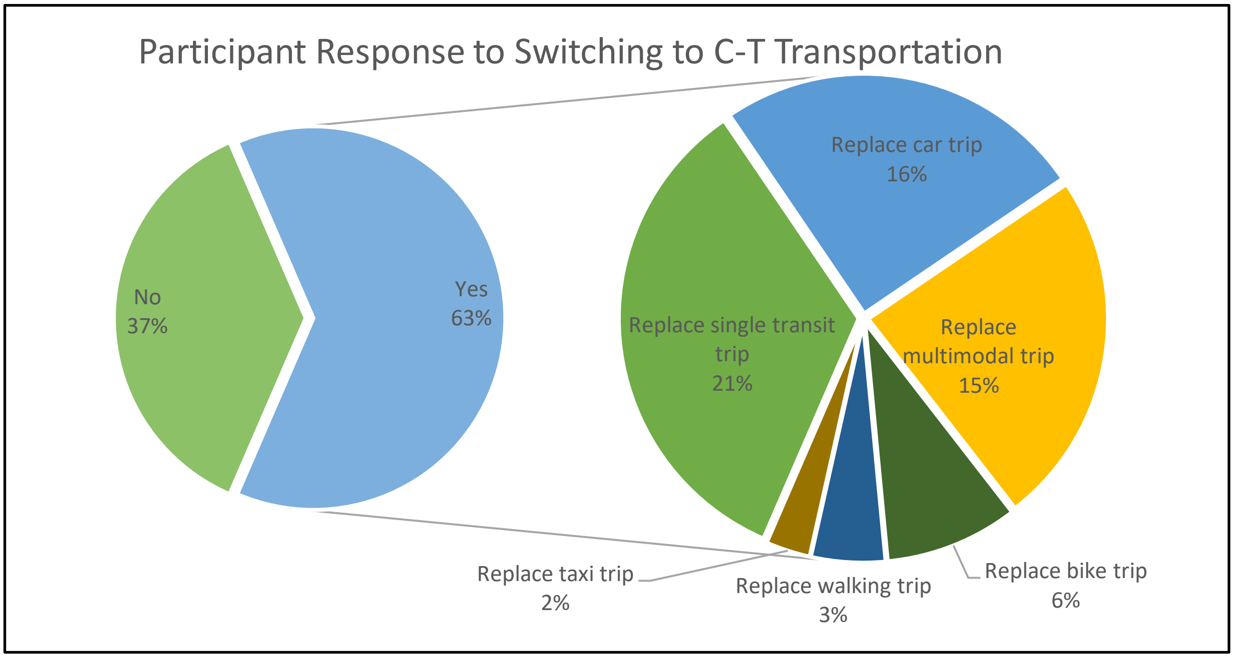

Figure 23. Source: Bachand-Marleau, Larsen &. El-Geneidy (2011):111, 114.

and rail transit. In a study of Capital Bikeshare trip origins and destinations in Washington, D.C. that found several important connections between bike share and public transit use, the study first found that "the highest bike share ridership occurred at locations close to Metro rail stations. Second, the study estimated that a 10% increase in bike share trips would directly contribute to a 2.8% increase in Metrorail ridership."[159] Other systems in cities such as London, Luxembourg, Paris, Montreal, Boston, New York City, and San Francisco uniformly show some of their highest usage rates in correspondence to rail and metro stations, with these stations serving as

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[158] Greg Phillip Griffin & Ipek Nese Sener. "Planning for Bike Share Connectivity," 7.
[159] Federal Transit Administration, *Manual on Pedestrian and Bicycle Connections to Transit, 73-4,* Greg Phillip Griffin & Ipek Nese Sener. "Planning for Bike Share Connectivity," 3.

"important feeders for the whole system."[160]

The potential of deploying bike sharing with express rail was also seen in a 2011 Montreal-based survey conducted in 2011 seeking to identify potential users of cycling-transit (C-T) integration and understand their needs and priorities.[161] As seen in Figure 23, a region-wide survey showed that 63% of respondents indicated they would be willing to combine cycling and public transit for some of their transportation. Of the willing respondents, 21% said they were most likely to replace single-mode transit trips with a C-T trip, followed by car trips (16%) existing multimodal trips (15%), bicycle (6%), walking (3%), and taxi (2%). More importantly however, the study showed certain transit users were more likely to use C-T trips than others. Specifically, over 80% of commuter train users expressed interest in C-T usage. With the highest interest coming from commuter train users connecting between multiple transit vehicles, these users were identified as prime candidates for C-T uptake strategies.[162] In their study the authors mirrored conclusions from car modal substitution studies, finding that opportunities for expanding C-T trips are "greatest for people living farther than 15 km from the city center," and that the greatest increase in C-T rates would result from "improving the integration of cycling and rail transit, particularly if combined with suburban cycling infrastructure improvements."[163]

5.4.5 Solution to C-T Barriers

For many station locations in suburban areas, numerous barriers exist to restrict C-T trips. Among the broader infrastructure and built form improvements necessary for cycling in suburban areas, more specific barriers to accessing transit stations via bicycle include: 1) perceived safety, 2) exposure to weather, 3) ownership of bicycles, and 4) available secure parking. Bike sharing provides at least partial solutions to the latter two of these barriers,[164] while initiatives to combine BSS with dedicated infrastructure improvements noted in the previous section also provide a solution to perceived safety. More specifically to the context of the GGH region, in a study investigating the C-T barriers that GO Rail users experience

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[160] Médard de Chardon, Caruso, Thomas, "'Success' Determinants," 212; Miriam Ricci, "Bike Sharing: Review of Evidence," 34.
[161] Julie Bachand-Marleau, Jacob Larsen & Ahmed M. El-Geneidy, "Much-Anticipated Marriage of Cycling and Transit: How will it Work?" *Transportation Research Record 2247* (2011): 109.
[162] Bachand-Marleau, Larsen & El-Geneidy, "Marriage of Cycling and Transit," 111, 114.
[163] ibid., 116.
[164] Greg Phillip Griffin & Ipek Nese Sener. "Planning for Bike Share Connectivity," 2.

Ravensbergen et al. asked 237 users who had biked to a GO station at least once in the past year about the challenges they experienced combining cycling with GO Transit. Four factors were consistently cited by the respondents: (1) unsecure and inconveniently designed bicycle parking at stations (most frequently mentioned at 33.76%), including issues of poor bike parking design and the security of parked bicycles; (2) travel safety concerns for the cycle part of the trip (second most frequent response at 22.36%), concerning lack of perceived safety mixing with traffic and the desire for dedicated bicycle lanes; (3) unclear and restrictive GO Train bicycle policy (third most frequent at 22.36%), mostly regarding the rush hour bicycle restriction, and; (4) impracticality of navigating stations with bicycles (identified by 15% of respondents), concerning difficulties of navigating stations due to station design.[165] Ravensbergen also asked users who do not cycle to GO stations their reasons for choosing not to. Following the leading issues of appearance and comfort, the most cited reasons by respondents were distance to the train station (33%), possibly indicating a lack of land use coordination with GO stations, followed by personal safety concerns of cycling to stations (27%) and concerns of bicycle security at stations (25%). On this last issue cited by respondents, Ravensbergen note that while only 25% of those who do not cycle to stations identified bicycle parking as a barrier, 44% of a sub-cohort of users who do not cycle to stations but expressed being somewhat to very interested in doing so identified security of their parked bicycles at stations as the main deterrent.[166] Through integrating effectively into station designs throughout the GO Rail regional network, a transit-integrated regional approach to bike sharing can respond to all of these concerns. One of the greatest advantages to users of bike sharing is the elimination of the burden of ownership (purchase cost, maintenance, storage/parking, theft concerns etc.). With a public bicycle, users can bypass the issue of secure parking at stations, avoid the need to bring their bike onto transit (which is restricted during important peak hours in most cities), and if a regional approach makes ubiquitous use of BSS at train stations across the region, users can take a second bike to their final destination as well.

Indeed, Ravensbergen et al. acknowledged the solutions bike sharing can provide when they wrote, "while some, of course, prefer the convenience of bringing their own bicycle on the train

[165] Léa Ravensbergen et al., "Biking to Ride: Investigating the Challenges and Barriers of Integrating Cycling with Regional Rail Transit," *Transportation Research Record 00:0* (2018): 3-4.
[166] Léa Ravensbergen et al., "Biking to Ride," 4-5.

to use it for both the first and last mile of their trip, coordinating Bike Share and rail systems could still encourage cycling to/from train stations. Indeed, others have similarly recommended that rail agencies provide multimodal offers such as access to shared bicycle systems, or integrated multi- modal fare cards, to encourage cycle–train integration."[167] However, in order to achieve significant C-T modal substitution from new riders it is important to take seriously the problem of perceived safety. A study among cyclists in Texas found that the presence of cycling infrastructure "had four times the effect on encouraging bike-and-ride among inexperienced riders relative to those with more experience."[168] Perceived safety and the presence of cycling infrastructure are particularly salient factors for BSSs—since BSSs are designed to be accessible and easily ridable and are most effective when accompanied by safe infrastructure. Noting the 2016 *GO Rail Station Access Plan's* prioritization of improving cyclist safety while accessing stations, Ravensbergen et al. also recommended dedicated cycling infrastructure within GO station property and throughout the municipalities they serve.[169] Ultimately, it is important to address all barriers to C-T transport with a multifaceted approach to enhancing urban cycling. While BSSs are indeed a particularly dynamic cycling intervention, the success of a BSS is nonetheless codependent on additional actions to address all C-T barriers. As research has indicated "that a comprehensive, coordinated package of cycling interventions is likely to have a greater impact than any single strategy in isolation,"[170] including such considerations into a comprehensive regional approach can be exponentially more effective than deploying a BSS alone.

5.4.6 Transit Station Integration

Integrating BSSs with RER and transit stations should be understood as an approach to feeder services as well as supplementing the provision of secure private bicycle parking. As BSS have been shown to increase the modal share of both public and private bicycles, the need for private bicycle parking might in fact increase. This increase is likely to be even more acute with the inclusion of quality infrastructure for station access. Just as the coordinated package of BSSs and cycling infrastructure contributes to complete streets designs, they too will contribute to an

[167] ibid., 8.
[168] Bachand-Marleau, Larsen & El-Geneidy, "Marriage of Cycling and Transit," 110.
[169] Léa Ravensbergen et al., "Biking to Ride," 8.
[170] Lindsay M. Braun et al. "Short-term Planning and Policy Interventions to Promote Cycling," 177-8.

increased requirement for a similar concept of *complete stations*. Complete stations include the infrastructure to accommodate all station access modes, including walking, cycling, feeder transit and kiss-and-ride, while often providing minimum vehicle parking as part of transportation demand management (TDM) strategies. Complete station designs should fully accommodate the needs of cyclists, including bike-and-ride parking and making rail platforms accessible, which also simultaneously improves accessibility for persons with disabilities.[171] BSSs add to the complete station design by improving equity of access for persons lacking private bicycles, and by eliminating the need for two bicycles to facilitate both the first and last mile for C-T users. While complete station designs that include cycling accommodations for both public and private bicycles may be costly, they are nonetheless cheaper than GO Rail's current model. This business model has always been simple: "build a station at a spot convenient to major roads and add free parking to attract passengers who might otherwise drive into Toronto."[172] While the Victoria Transport Policy Institute estimates the installation cost per space of bike-and-ride as $140-$800, the installation cost per space of park-and-ride is $10,000-$12,000.[173] With the current model inducing inflated demand for driving and park-and-ride, and just 1% of GO rail passengers accessing stations by bicycle,[174] complete station designs will indeed be a necessary component of plans to prioritize RER access for pedestrians, cyclists and transit riders.

5.4.7 Determining Bike Sharing Type

While Bike Share Toronto remains the most dominant service provider for bike sharing in the GGH, a regional approach to transit-integrated bike sharing need not necessarily be constrained to one provider. Doing so would be irreconcilable in the face of the City of Hamilton's bike sharing program, SoBi Hamilton, which uses the differing smart bike delivery platform. Throughout the various areas where bike sharing might operate across the GGH region, the selection of BSS type and provider should reflect the direction, priorities and needs of the area and its host municipality. Furthermore, regardless of what system type is and provider is used, in order for a BSS to integrate effectively with regional transit and provide the basis for mobility in

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[171] John Pucher & Ralph Buehler, "Integrating Bicycling and Public Transport in North America," *Journal of Public Transportation* Vol. 12 No. 3. (2009): 101.
[172] Oliver Moore, "GO Transit Calls Time on Free Parking," *The Globe and Mail*, April 6, 2018.
[173] Victoria Transport Policy Institute. "Bike/Transit Integration" TDM Encyclopedia. Last updated 25 August 2016. http://www.vtpi.org/tdm/tdm2.htm.
[174] Moore, "GO Transit Calls Time on Free Parking."

which complete communities and their inhabitants can rely on, it is important that the system is well maintained and provides a similar level of service reliability to whichever fixed-route transit system it interfaces with. Hence, it is argued here that a market-led approach should not be considered, and instead a public-private partnership (P3) should be sought. This is to protect against market uncertainties and prevent service disruptions to a potentially fundamental element of a regional transit network. Take for example, the retreat of Ofo, previously the largest global bike sharing provider, from the German, Israeli and Australian markets while also significantly reducing operations in both the UK and the United States. Laying off employees across all of its American sectors, the company is reported to be "reorienting to focus on markets that will help it become profitable."[175] In addition, BikePlus Project Manager Chris Slade noted that market-led approaches have difficulty safeguarding against inequitable service practices where private operators respond to the spatial distribution of usage levels by redistributing only in the most profitable areas and reducing or eliminating coverage in areas of lower profitability. "It's not that dockless bike sharing operators can't redistribute their bikes, that's not the case at all, but there's good and there's bad practice out there," explained Slade. In market-led, permit based approaches, however, there's a difficulty with formal controls.[176]

Using a P3 approach to selecting and procuring BSSs ensures better overall reliability and control for the transportation authority, helps to guarantee a focus on service versus profit, and also aligns with current procurement and operating trends in the transit industry. In delivering and operating the future RER system, GTHA regional transportation authority Metrolinx is using a mix of both traditional in-house service management and "Alternative Finance and Procurement (AFP) methods, with private-sector partners taking a wider range of system integration and performance risk." Already Metrolinx has a significant level of experience with P3 arrangements, with the UP Express, East Rail Maintenance Facility, and Eglinton Crosstown project all based on public-private partnerships. Meanwhile, Metrolinx already contracts with Bombardier to operate and maintain its GO Rail train service.[177] Thus, in terms of procurement

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[175] Alison Griswold, "Bike-sharing company Ofo is dramatically scaling back in North America," *Quartz*, 18 July 2018, Url: https://qz.com/1331368/bike-sharing-company-ofo-is-dramatically-scaling-back-in-north-america/.
[176] Chris Slade, interview.
[177] Metrolinx, *GO Regional Express Rail Initial Business Case*, 2015. Url: http://www.metrolinx.com/en/regionalplanning/projectevaluation/benefitscases/GO_RER_Initial_Business_Case_EN.pdf.

processes and operations, securing BSSs via P3 arrangements would be a logical extension of the RER delivery program's current trajectory.

Regardless of the procurement and operations models, the most important aspects of a transit-integrated regional bike sharing approach is threefold. Firstly, the system must be reliable and effective as both an independent transportation mode and one that interfaces with fixed-route transit. In Bike Share Toronto manager Sean Wheldrake's experience, users value predictability. "Through all these various systems it seems that what people like the most is when bikes are left in places where they know they can find them," Wheldrake explained. "[Original] systems that existed before docked systems basically functioned [with the same predictability, for example] you go to the major train station and lots of bikes will be there." For predictability, Bike Share Toronto's system is organized like the bus stops along the route of a transit line—deploying bike sharing stations "every 300 or 500m for predictability."[178] Secondly, a regional bike sharing program must respond to the local character and needs of the service area and host municipality. In growth centres with an already effective anchoring fixed-route transit system and a higher density of residents and destinations, a docked system might be most appropriate; while other locations with less significant trip generating destinations might be more suited for geo-fenced smart bike system. As SFMTA senior transportation planner Heath Maddox noted, areas with a lower density might be more appropriate for smart bikes, especially if a limited budget would otherwise result in only a small number of docking stations.[179] Thirdly, it is essential that such a program maintains a simple and seamless front-end customer experience. In this regard, it does not necessarily matter how many different BSSs are operating across a region, what is more important is that they are all integrated under one platform. In order for such a multimodal system to be competitive against the convenience of driving a personal car, users should have a seamless experience across different transit modes, regardless of how back-end systems manage it. In this, users should not be required to use different smart phone apps for the beginning and end portions of their journeys, or have to maintain multiple payment types for a single trip. As long as these three aspects are managed effectively, the selection of a bike sharing platform should be successful.

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[178] Sean Wheldrake, interview.
[179] Heath Maddox, interview.

5.4.8 Fare Integration

For a regional transit system that uses multiple transport modes from beginning to end of its user's journeys, a seamless and easy user experience is paramount—the beginning of which starts at the point of purchase. With Metrolinx's PRESTO card already offering a readily available digital platform for the GTHA, fare integration between BSSs and transit such as RER could use this as its medium. A number of areas worldwide already offer fare integration systems to a varying degree, such as Hong Kong's Octopus card, London's Oyster card, the Carte Orange in Paris, and the Clipper card in the San Francisco Bay Area.[180] To promote cycling and transit as complementary rather than competing modes and as part of a TDM strategy, Braun et al. suggested discounting rates for combining bike sharing and transit or incorporating a single fare system entirely, with the latter expected to yield significant results in terms of increases to C-T trips.[181] The incorporation of pre-purchased fare passes is considered one of the most significant determinants to transit usage, with multimodal transportation cards proliferating worldwide. In a 2007 study throughout GTHA, Bandoe and Yendeti examined the impact of pass ownership on daily number of transit trips. Their results supported the previous findings of a similar Swiss study in 2000 by Axhausen et al., both concluding that transit pass ownership was "the single most important factor determining transit usage." Furthermore, an additional Swiss study by Simma and Axhausen in 2001 suggested that "committing to a specific mode by purchasing a mobility tool reduced the usage of other modes."[182] The enabling/disabling influence of integrated payment cards highlights the necessity to integrate bike sharing front-end fare systems with those of the transit systems they seek to provide first/last mile services. Indeed, while a study of BIXI users in Montreal also found that those users with yearly memberships were most likely to integrate their rides with transit,[183] further integrating fare systems into a single platform can encourage a potential surge of traditionally transit-only riders to do the same with BIXI. Such action is likely the most fundamental determinant of integrating and encouraging BSSs as a first/last mile service for RER and transit in underutilized areas.

[180] Maria Kamargianni et al. "A Critical Review of New Mobility," 3295-6.
[181] Lindsay M. Braun et al. "Short-term Planning and Policy Interventions to Promote Cycling," 177-8.
[182] Maria Kamargianni et al. "A Critical Review of New Mobility," 3297.
[183] Julie Bachand-Marleau, Jacob Larsen & Ahmed M. El-Geneidy, "Marriage of Cycling and Transit," 116.

5.4.9 *Mobility as a Service (MaaS)*

While fare integration likely represents the best starting point with the most impact for increasing multimodal trips, further integration is available and perhaps necessary to regional mobility management, and maximizing car-to-transit modal shift in suburban areas. As a leader in the evolving shared economy of transportation, MaaS platforms can be the key to complete and effective integration of BSS with regional transit, and reciprocally bike sharing programs can serve as an initial testbed for MaaS development in further regional transportation network applications. With the large service area of RER and the varying urban-suburban-rural environments it spans, bike sharing programs can be effective first/last mile options in growth centres while not immediately in others. Moreover, just as walking, cycle access to RER stations for most people is limited by distance—estimated at approximately 6km.[184] In autocentric areas where bike sharing is not immediately applicable or distances are too great, the challenge remains how to connect people to RER systems without using costly park-and-ride services, which would perpetuate autocentric design and thus defeat the purpose of smart growth, TOD and new urbanist strategies to begin with. To account for this and provide effective RER access and car modal substitution, multiple modes of flexible transportation can be employed through the concept of mobility as a service (MaaS). As stated by the National Association of City Transportation Officials (NACTO), "a crucial complement to a transit network is a suite of flexible, convenient, and affordable mobility choices—walking, bicycling, shared mobility, and on-demand rides—that, together with fixed route transit, allow residents to avoid the costs of car ownership and make proactive decisions about each trip they take."[185] In this sense, BSSs can eventually be incorporated into a broader array of complementing flexible transport services under MaaS, offering major benefits for people in low density areas and enabling smart growth and new urbanist design changes in a more cost-effective way compared to underutilized feeder bus services.[186]

As Ambrosino et al. explained, the essential idea of MaaS is "to see transport or mobility not as a

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[184] Metrolinx, *Active Transportation Background Paper – Full Report: Technical Paper 1 to Support the Discussion Paper for the Next Regional Transportation Plan,* prepared by Steer Davies Gleave (2015), 55. Url: http://www.metrolinx.com/en/regionalplanning/rtp/technical/01_Active_Transportation_Report_EN.pdf.
[185] National Association of City Transportation Officials (NACTO). *Transit Street Design Guide (*Washington DC: Island Press, 2016), 2.
[186] David A. Hensher, "Future Bus Transport Contracts Under a Mobility as a Service," 94.

physical asset to purchase (e.g. a car) but as a single service available on demand that incorporates all transport services from cars to buses to rail."[187] By connecting a number of complementary transportation services into one platform, users can buy mobility service packages instead of the means of transportation itself as a means of satisfying complete door-to-door mobility needs. MaaS is based on three main elements that can together provide users with seamless intermodal journeys: 1) *Ticket & Payment integration*: where one smart card or ticket is used to access all the modes taking part in the service and one account is charged for their use; 2) *Mobility packages*: where customers can pre-pay for a specific amount (in time or distance) of a combination of mobility services based on travel needs; 3) *ICT integration*: where a single application or online interface is used to access all information, plan trips and manage all intermodal use.[188] Users can choose to use a pre-purchased mobility package or pay-as-you-go for combinations of transportation such as public transit, bike sharing, car sharing, car rental, taxi or Uber/Lyft, as is reflected amongst the anticipated elements shown in Figure 24. Public transit would still have a crucial role in

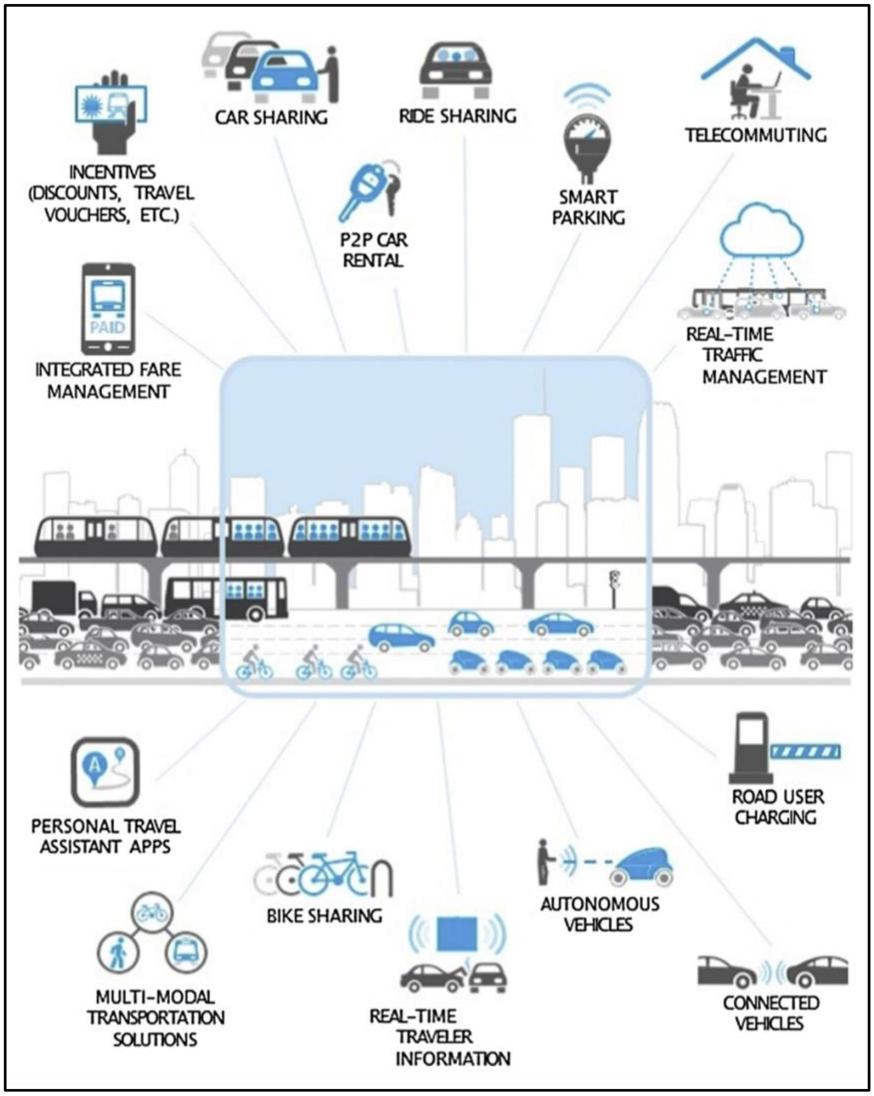

Figure 24. Theorized potential of a MaaS future. Source: Hensher (2017): 88.

[187] Giorgio Ambrosino et al. "Enabling Intermodal Urban Transport," 181.
[188] Maria Kamargianni et al. "A Critical Review of New Mobility Services for Urban Transport." *Transportation Research Procedia 14* (2016): 3295.

such a system, where conventional fixed-route transit such as LRT, BRT, subway, RER, streetcar and other bus services "serve as main urban axes/corridors and flexible/shared transport services integrate into it for feeder, last mile and target groups services." Consequently, Ambrosino et al. explained that regional transit authorities and/or operators are best suited to oversee and manage MaaS initiatives.[189] In the capacity of an umbrella organization, transit authorities could manage fixed-route transit services while providing a kind of broker service to coordinate the various flexible transport services that feed into them.[190] This type of organizational structure can be useful in the context of a mobility management agency in the GTHA and GGH region, where multiple transit agencies are currently organized around municipal boundaries. Today these municipal boundaries are more blurred than ever, with transportation patterns functioning on a more regional scale showing many people crossing multiple municipal boundaries on a daily basis. For a transit-integrated regional approach to bike sharing, either one bike sharing provider can take a leading region-wide role as is seen in European examples, or a number of different municipally procured BSSs can integrate into a broader system. Either way, BSS can serve as a readily available testbed for further deployment of MaaS systems and additional flexible mobility services.

In 2016, the European Commission stated their expectation that "a paradigm change in transportation is expected to take place through the emergence of Mobility as a Service (MaaS), where the service providers could offer travelers easy, flexible, reliable, price-worthy, and environmentally sustainable everyday travel."[191] Part of this understanding arose from a number of MaaS pilots conducted throughout Europe, such as the UbiGo trial in Sweden. The trial involved 70 households and 190 users in Gothenburg, Sweden, between November 2013 and April 2014. Users agreed to pre-pay for a monthly mobility package that included taxis, car sharing and rental, bike sharing, and public transit, which they chose in advance based on what they felt best suited their mobility needs. Advantages stated by users were that "it became easier to pay for travel and that the service gave them access to more modes of travel," while the only disadvantages stated were that it was initially difficult to choose the level of subscription, and

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[189] Giorgio Ambrosino et al. "Enabling Intermodal Urban Transport," 182.
[190] ibid., 181-2; David A. Hensher, "Future Bus Transport Contracts Under a Mobility as a Service (Maas) Regime in the Digital Age: Are they Likely to Change?" *Transportation Research – Part A 98* (2017): 91.
[191] European Commission *Work Programme 2016-2017: Smart, Green and Integrated Transport* (2016), 51. Url: http://ec.europa.eu/research/participants/data/ref/h2020/wp/2016_2017/main/h2020-wp1617-transport_en.pdf.

that some transit personnel were unaware of the pilot taking place. All users involved in the trial opted to continue using the service after the trial ended. Interestingly, there was a considerable amount of unused travel allocations for most users each month. On average, 14% of monthly public transit services went unused, while 31% of monthly car services were unused, possibly signifying an exaggerated perceived need for automobiles.[192] Another two pilots are entering testing phases in Helsinki and Berlin. The Helsinki pilot, based on the smartphone app *Whim* by the firm *MaaS Global,* offers three options: pay-as-you-go, monthly mobility packages, or 'ultimate freedom' where users pay a standard fee for unlimited use of all included transport options, earning extra points for using public transit and other low-carbon options such as bicycles and electric vehicles.[193] The Globe and Mail recently published an article highlighting *MaaS Global's* interest in Toronto as the firm's first expansion outside of Europe. Yet, while Metrolinx's most recent RTP highlights an expressed interest in MaaS systems and makes explicit mention of *MaaS Global* as a leading provider,[194] the agency nonetheless was hesitant to enter into service agreements without additional research into the concepts.[195]

While already being used to access/egress transit services, effective integration can significanly improve BSS's appeal and ability to serve as an effective first/last mile solution to RER and other express transit such as subway, LRT and BRT. In this capacity, bike sharing can increase access and ridership for regional and express transit, while eliminating the necessity of driving and park-and-ride at stations. A coordinated package of cycling infrastructure and BSS can solve virtually all access to C-T barriers, notwithstanding weather impacts, and contribute to complete station designs. While the reasonable starting point lies in fare integration, BSS integration can also serve as a readily available testbed for future expansion of flexible mobility services under MaaS. Using bike sharing as a pilot, institutional actors can analyse outcomes and evaluate necessary adaptations and programming provisions for more broad MaaS services in the future. Likewise, MaaS can serve as the framework in which to apply flexible and shared mobility services such as bike sharing, seamlessly integrate them with fixed-route transit, and provide

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[192] David A. Hensher, "Future Bus Transport Contracts Under a Mobility as a Service (Maas) Regime in the Digital Age: Are they Likely to Change?" *Transportation Research – Part A 98* (2017): 88-9.
[193] ibid., 89.
[194] Metrolinx, *2041 Regional Transportation Plan, 69-70.*
[195] Oliver Moore, "Toronto Misses Opportunity to Implement Integrated-Mobility Transit System," *The Globe and Mail,* July 9, 2018, A10.

effective alternatives to car ownership and autocentric design. Of MaaS, BikePlus Project Manager Chris Slade stated his opinion: “MaaS is very much the way that the transport sector is going and I think that it could be the panacea for reducing car use, but I think there needs to be a behaviour change. People are very much addicted to their cars and the way they use them and I think there’s an industry skepticism about whether just one app is going to be the one thing that’s actually going to get people out of their cars.”[196] Echoing Slade’s comments, it is argued in this paper that technology alone will not be the answer to changing transportation behaviours. Rather, changes to the built environment are also critical to changing transportation behaviours. Complete communities, a more transit-supportive built environment such as TOD, and ultimately a coordinated shift away from suburban sprawl must be met by alternative transportation options. In a comprehensive regional transit system, MaaS can serve as the integration medium for BSSs, and help facilitate and support the necessary built environment change.

5.5 Bike Sharing, Built Environment and Public Realm

The design of Urban Growth Centres can be enhanced to satisfy Smart Growth principles and New Urbanist designs if bike sharing was included as a core design principle. Implementation trends of bike sharing programs primarily in cities’ CBD is indicative of an interdependency between BSSs and a built form of higher density and mixed use. Low-density, auto-centric suburban sprawl is largely incompatible with uptake of bike sharing or cycling at any significant rate. In this, the size of a municipality is not the determining factor per se, but rather the built form. “Small town Ontario has suffered probably worse than big cities with the sprawl issue,” explained Bike Share Toronto manager Sean Wheldrake. “It’s really hard to get from point A to point B in say, Aurora, unless you have a pickup truck just because of how it’s been built out. But if you went to Timmins in Northern Ontario 100 years ago, it was easier to walk or bike around than it is now because everything was built within walking distance, but now everything has become big-box. So, the town is not the problem, it’s the built form in the town and how its changed.”[197] Indeed, autocentric design is the primary deterrent to walking, cycling and bike sharing in suburban towns. Given bike sharing’s relationship to a density of mixed-uses, considering bike sharing as a core element in the planning and design of Urban Growth Centres

[196] Chris Slade, interview.
[197] Sean Wheldreake, interview.

can serve to encourage and facilitate the built environment changes that constitute complete communities.

In the case of creating a true regional transportation network, the capabilities and benefits of BSSs cannot be fully realized without prioritizing land use planning towards density and complete communities on a local scale, and linking those communities to effective transit on a regional scale. In this, bike sharing programs can and should be used as the necessary local mobility linkage to regional transit. Locally, BSSs can improve communities that incorporate Smart Growth strategies and New Urbanist design in the Urban Growth Centres of the GGH region, such as compact built form, mixed-use zoning and building designs, complete streets, and transit-oriented development (TOD). A Sustainable Transportation paradigm that includes a coordinated cycling intervention package of bike sharing and protected cycling infrastructure can provide the foundation for such New Urbanist designs, while advancing Smart Growth objectives that seek to address autocentric low-density suburban sprawl. In a New Urbanist and TOD approaches that incorporate complete streets and communities, BSSs can be positioned, firstly; to serve as first/last mile solutions to RER and any other high order transit, and secondly; to facilitate local mobility and economic interaction within Growth Centers and surrounding communities. Bike sharing stations can also support a more vibrant public realm and the multimodal complete streets that New Urbanism engenders by enabling and promoting human-scaled movement and providing an anchor for placemaking activities. BSSs applied to TOD areas can also significantly expand the catchment area of GO RER or transit stations, thereby enabling expansion of TOD areas themselves. Ultimately, by serving a broad range of Smart Growth and New Urbanist design objectives either directly or indirectly, a coordinated strategy to promote transit-integrated BBSs and cycling infrastructure within expanded TOD neighbourhoods can create the foundation of complete communities in Urban Growth Centres. What follows from this argument is a supportive analysis of how BSSs improves and supports New Urbanist designs, complete streets, and TODs as a means of achieving better urbanism and Urban Growth Centre targets.

5.5.1 Bike Sharing and New Urbanist Design in Growth Centres

New Urbanist design emphasized the public realm and inherently fosters traffic reduction and calming, which bike sharing can play a pivotal role. Connecting New Urbanism directly to the

ST paradigm, Schiller, Bruun & Kenworthy wrote that land use policies and programmes "that help to create more accessible and multimodal communities are an important part of mobility

Box 1. New Urbanism Neighbourhood Design Features

- Development is compact and mixed, with a variety of building types, including commercial-residential mixed-use, and includes various other commercial and institutional structures close together.
- The community has a discernible activity centre with a transit station. This is often a plaza, square or green, and sometimes a busy or memorable intersection.
- Most dwellings are within a five-minute walk from the centre. Streets are designed for walking and cycling, with sidewalks on both sides, bike lanes where needed, good crossings, traffic calming features used to control motor vehicle traffic speeds, and other features to encourage non-motorized travel.
- Special attention is paid to protecting the public realm and creating quality public spaces, including sidewalks and paths, parks, streetscapes and public buildings.
- Buildings at the centre are placed closed to the sidewalk and to each other, creating an urban sense of spatial definition.
- There are shops and services sufficient to meet common household needs within the neighbourhood (i.e. complete communities).
- There are parks, trails and playgrounds not more than 200m from each dwelling.
- Thoroughfares are relatively narrow and shaded by rows of trees that slow traffic an create an appropriate environment for pedestrians and cyclists.
- Networks of highly connected roads and paths provide multiple routes between destinations, increasing accessibility and distributing traffic.
- Parking supply is minimized and managed for maximum efficiency.

Source: Schiller, Bruun & Kenworthy (2010), 227.

management."[198] New Urbanism identifies the connected street network as one of its essential design elements. To encourage walking, biking and transit use, the streets are narrow and traffic calmed for the comfort of human-scaled mobility. In retrofitting areas with New Urbanist designs to "repair neighbourhoods and city environments hurt by traffic,"[199] bike sharing stations can be employed. By siting bike sharing stations on the street, they can contribute to narrowing the RoW, increasing pedestrian visibility at intersections, and calming traffic by "demarcating and protecting pedestrian and cyclist space."[200] A reference list of New Urbanist design is provided in Box 1.

Bike sharing station siting standards recommend stations be placed contiguously at 3-5 minute walking intervals, aligning with the scale of the 5-10 minute walk New Urbanist neighbourhood

[198] Schiller, Bruun & Kenworthy, *Sustainable Transportation,* 227.
[199] ibid., 239.
[200] National Association of City Transportation Officials (NACTO), *Bike Share Station Siting Guide,* 2016, 9, 20. Url: https://nacto.org/wp-content/uploads/2016/04/NACTO-Bike-Share-Siting-Guide_FINAL.pdf.

while facilitating the more localized movement in such neighbourhoods.[201] Research has also shown that a bike sharing station that replaces an on-street parking spot increases the economic activity at nearby stores by 52% over a car due to increased turnover and higher patronage rates of pedestrians and cyclists over motorists.[202] This is well aligned to support complete communities and range of everyday amenities that New Urbanist neighbourhoods provide. Moreover, since bike sharing stations double as a mobility service and a high-convergence piece of street furniture, stations can contribute to enriching underutilized public spaces. Placing stations next to the curb on corners can serve to enclose the pedestrian space from the RoW, creating a more comfortable environment and opening possibilities for further placemaking activities. For streets containing excess negative space, bike sharing stations can fill voids such as setbacks to reintegrate properties into the public realm. Meanwhile, siting standards also stress the need for good visibility and lighting near stations, which, if practiced, increases street safety and eyes on the street.[203]

New Urbanist design also stresses the importance of public space in forming the central point of neighbourhoods.[204] If rejuvenating or creating them, bike sharing can play a central role. Plazas parks and squares provide a mutually beneficial opportunity for bike sharing stations and public space alike. In New York City, a road closure and bike sharing stations were used to create a car-free zone that repurposed a street causing traffic issues into a pedestrian plaza. This enlivened a previously undesirable and underutilized space into a comfortable social gathering spot, while also contributing to traffic calming and more sustainable transportation.[205] Using similar strategies around GO RER stations in Urban Growth Centres can contribute to both enhanced public space and provide increased access to GO Rail transit. In an Urban Growth Centre that employs New Urbanist design to establish a cluster of pedestrian shed neighbourhoods around a GO Station; BSSs can help establish social and economic cohesion of the cluster by simultaneously providing station access, connecting the central public spaces of each neighbourhood shed, and providing end-to-end mobility for inter-neighbourhood travel. Hence,

[201] NACTO, *Bike Share Station Siting Guide, 6.*
[202] ibid., 11.
[203] ibid., 7, 22.
[204] Elizabeth Plater-Zyberk, "Eleven," 79-81.
[205] NACTO, *Bike Share Station Siting Guide, 34.*

bike sharing systems can directly enhance and support New Urbanist design in multiple ways; most particularly in public realm enhancements, local mobility and improved street design.

5.5.2 Defined by the Street: Building Density Without Car Use

As New Urbanism dictates, designing Urban Growth Centres should start with quality street design. Without it, intensification of residential densities in Urban Growth Centres can easily exacerbate auto-dependence. "It's not just because of the population density, it's because of built form," stressed Wheldrake. "If it was just a car-centric place—I think of downtown Mississauga, which basically has a dense population but has a big mall in the middle, it's not like a Parisian street—[then] it's pretty scary riding your bike to the mall. It is dense, but the built form is so bad that is prevents bike share use."[206] Former Chief Planner of Vancouver (2006-2012) Brent Toderian also sees the street as the essence of new urbanist design and smart growth approaches such as TOD.[207] While he sees building density with amenities and diversities as important to ensure livability, Toderian also highlighted public realm design as a critical aspect of high-density development—specifically, how buildings are "going to land and how they're going to strengthen and contribute to the street." Toderian insists on carefully designing the podium and tower-type development common of Vancouver's core to ensure high mixed-use density that still affords an enjoyable experience on the street. With strong public realm designs, Toderian suggests you can get the best of both worlds: "you get the mid-rise human scale for walkability et cetera, and you get the density—the body heat—that comes from the towers in combination in our downtown. That's vertical *urbanism* to me . . . vertical *sprawl* is if you ride down the elevator of your tower, go down into your parking garage and vomit out onto an expressway—that is vertical sprawl, that's auto-dependant tall towers." In this context, New Urbanism and smart growth draw a fine line, yet the crucial difference here between vertical sprawl and vertical urbanism is the character and quality of the street. Hence, a critical element of Toderian's vertical urbanism, one which is critically intertwined with quality urban and public realm design, is multimodal streets. Principally, Toderian stressed, "it's about multimodal city making: prioritizing—not balancing—walking, biking and public transit, in that order." With Toderian's

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[206] Sean Wheldrake, interview.

[207] Brent Toderian, "Episode 112: The Vancouver Model," interview by Jeff Wood, *Talking Headways: A Streetsblog Podcast*, September 1, 2016, audio, 40:11, http://streetsblog.libsyn.com/episode-112-the-vancouver-model.

focus on multimodal street design, Vancouver set out to build 139km of bike boulevards across the city,[208] the most extensive network in North America. By prioritizing multimodal street design in density intensification, Vancouver was distinguished in 2010 as having the most bicycle commuting (3.7% of city workers, a 2% increase in 4 years), highest percent of female bicycle commuters (37%), and safest cycling (approx. 1 fatality/10,000 cyclists) out of any Canadian city.[209] Surely, when it comes to cycling uptake, smart growth strategies and new urbanist design, lessons can be drawn from Vancouver and their approach to public realm and the emphasis on quality street design.

5.5.3 Streets as Public Space & Human-scaled Mobility

If TOD is one side of a smart growth/New Urbanism coin, complete streets is the other. The aim of complete street designs is to reconceptualise the nature of streets from "traffic sewers" to a mixture of public space and effective transportation grids for all modal types. Schiller, Bruun and Kenworthy explained, "such streets are not only tasked to accommodate private motor vehicles, but also pedestrians, cyclists, transit and nature in the form of more trees and gardens or other greenspace. They are multimodal transport links as well as places for social life and active living . . . Complete streets restore the balance in the public environment in favour of non-auto users and the social function of city spaces."[210] To support the higher density concentration of urban centres and TOD areas, complete streets generally seek to move more people with less space, measuring this by person throughput and capacity rather than vehicle throughput and speed.[211] After all, while many argue that congestion is a natural feature of any vibrant city, "it is not moving vehicles per se that nourish the city, but people and goods."[212] Transportation planners and traffic analysts in Copenhagen understood this when, between 2008-09, Traffic Director Niels Tørslov conducted an urban experiment on the Nørrerogade, a principal shopping street and major thoroughfare of Copenhagen's Nørrebro district. After struggling with congestion and

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[208] Figure as of 2010. Bicycle boulevards: a modification of traffic-calmed streets specifically designed to facilitate cycling. Special pavement markings and signage reinforce bicycle priority on such streets, which includes right of way when riding through most intersections and special bike traffic signals to cross (Pucher, Buehler &Seinen, 2011: 466).
[209] John Pucher, Ralph Buehler, Mark Seinen, "Bicycling Renaissance in North America," 463, 470.
[210] Schiller, Bruun & Kenworthy, *Sustainable Transportation*, 239-40.
[211] National Association of City Transportation Officials (NACTO). *Transit Street Design Guide, (*Washington DC: Island Press, 2016), 5; Transport Canada, *Bike Sharing Guide*, 16.
[212] Montgomery, *Happy City*, 220.

over-capacity, Tørslov diverted car commuters to wider arteries, established bus-only lanes, doubled up on bike lanes and widened sidewalks. As Montgomery described, the effect was substantial almost immediately. By late 2009, "commuter car traffic had fallen by half, bus passengers reported shorter trips. Seven thousand new cyclists had joined the daily parade . . . and the restaurants and shops on Nørrebrogade had spilled out onto the generous sidewalks" to enhance the public realm.[213] As applied in Copenhagen by Tørslov and promoted in Vancouver by Toderian, reorganizing street use in terms of the *green transportation hierarchy*, which prioritizes travelers who use less space, serves to enhance overall transportation networks, reinvigorate urban streets, and help "make the density equation work."[214]

Implementation of complete streets policies in North America is not as comprehensive as in places like Copenhagen. In Ontario, one of the more robust complete streets policies is the City of Toronto's recent *Complete Streets Guidelines*, released in 2017. The guidelines consider complete streets through the lens of three main components: streets for people—emphasising streets as a human environment by making streets safe, accessible and connective for road users of all modal types; streets for placemaking—emphasising streets as important public spaces for people to socialize, build community and shape experiences of their city; and streets for prosperity—emphasising the street's environment as a critical aspect to the city's economic vitality.[215] Toronto's *Complete Streets Guidelines* also include provisions for the inclusion of bike sharing stations in street treatments, the first time Bike Share Toronto manager Sean Wheldrake has seen them included in streetscape policy so directly.[216] "Streetscape design has a huge effect on bike share," Wheldrake explained. "One of the big reasons is street design currently does not incorporate bike share as part of the design network. It wasn't thought of—bikes were hardly thought of."[217] With the prioritization of motorized vehicles, and many uses competing for space in Toronto's sidewalks and narrow (RoW), finding room for bike sharing stations in ideal locations is a difficult task. In American streets, where RoWs are wider, siting a

[213] ibid., 219-220.
[214] "Multi-modal Level-of-Service Indicators" TDM Encyclopedia, Victoria Transport Policy Institute, last updated 19 July 2017, http://www.vtpi.org/tdm/tdm129.htm; Montgomery, *Happy City,* 220; Brent Toderian, "The Vancouver Model," *Talking Headways: A Streetsblog Podcast.*
[215] City of Toronto. *Toronto Complete Streets Guidelines: Making Streets for People, Placemaking and Prosperity.* 1st ed., vol. 1 (2017), 7.
[216] City of Toronto. *Toronto Complete Streets Guidelines,* 90-1, 98.
[217] Sean Wheldrake, interview.

bike sharing station can also be difficult for similar reasons. Partially due to San Francisco's infamously narrow sidewalks, SFMTA senior transportation planner Heath Maddox sites most station locations in the roadway, requiring parking removal/conversion. Maddox notes one of the biggest challenges to siting bike sharing stations as "parking removal and people's sense of ownership, entitlement and expectation that there will always be a place to store their vehicle in the public RoW." In response to these issues, Health reflected complete streets policymaking when he explained, "streets are not just to store cars and not just to make money off cars either, the public RoW is managed to achieve public policy goals . . . some of them are related to reducing private vehicle use and increasing the use of transit and walking and biking."[218] While changes are happening to the ways we understand streets in North America, the predominance of the use and street space allocation of automobiles continue to create substantial resistance in both places like Toronto and San Francisco. More prominent in many urban centres of Western Europe, complete streets policies and ideas like the green transportation hierarchy continue the struggle for merit in North America's car-dominated streets at the expense of almost every other mode of transport.

Indeed, as Figure 25 clearly shows, cars are space hogs[219] that negatively impact not only other

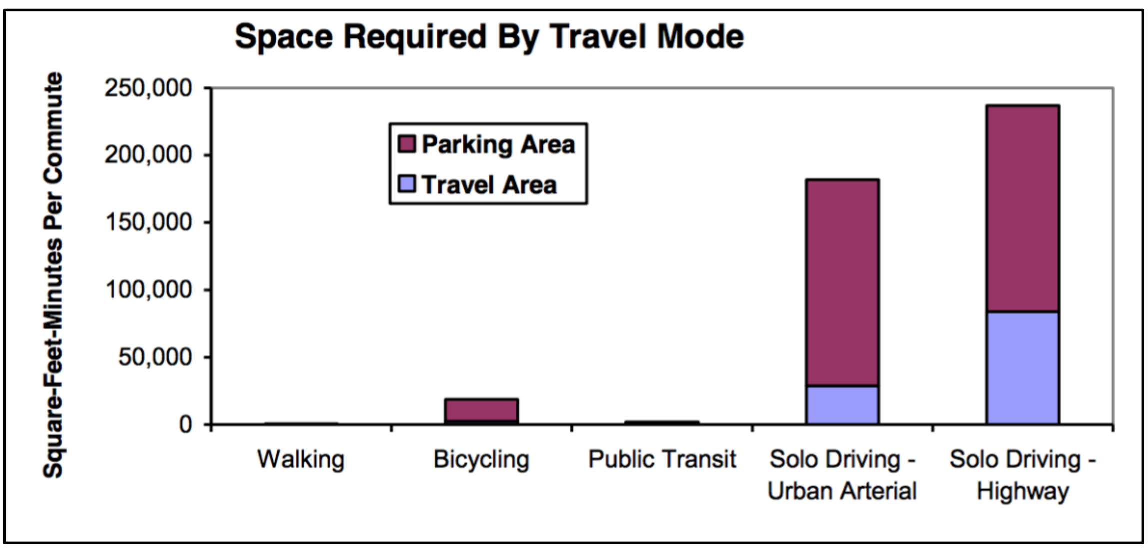

Figure 25. "Automobile travel requires far more space for travel and parking than other modes." Source: Victoria Transport Policy Institute (2017).

[218] Heath Maddox, interview.

[219] When standing still, even the smallest cars still take up approximately 150ft^2 (14m^2), or 7.5 times the space used by a person on a bike or bus. These numbers diverge further with speed: a single person in a car driving 50km/h takes twenty times more space than a person riding the bus at the same speed, and 30 times more space than a cyclist travelling at 15km/h (Montgomery, *Happy City, 220).*

transportation modes such as transit and cycling, but the public realm as well. A number of scholars have written on the problems of creating urban environments without a sense of belonging and place—Jane Jacobs being only one of the most prominent. Schiller, Bruun and Kenworthy wrote, "low-density auto-dependant suburbs where there are few, if any, small local shops and where little walking occurs can suffer from a lack of community feeling and a loss of street life that was common in North American and Australian suburbs only some 40 to 50 years ago."[220] Similarly, Duany, Speck & Lydon distinguish streets not just as traffic conduits, but as public spaces and "perhaps the primary location of American civic life." As such, thoroughfares—especially neighbourhood streets—should be designed as places of social engagement and gathering.[221] Dunham-Jones and Williamson echo this when explaining that the distinguishing factor of contemporary mixed-use developments most successful in achieving their 'true downtown' social aspirations is the walkable, human-scaled integration of their uses, and the quality of public space between them.[222] Recently, increased attention to the messy public realm of streets has "challenged public space to embrace multiplicity over unity," while simultaneously reinforcing their role in constituting civility—described by Aristotle as the art of living together well. Highlighting the importance of designing streets as public space, Dunham-Jones and Williamson argued that civility and the amenities of urban public life are in fact "precisely what compensate the residents of new downtowns for the loss of suburban private space."[223] Hence, maintaining the dominance of cars in growth center streets severs the public space that would otherwise be the center's strongest asset. Bike Share Toronto manager Sean Wheldrake saw this as an inversion of the problems he faces when siting for bike sharing stations in the dense Toronto core: "if you go to the very suburban places of Toronto like Scarborough or parts of North York there is room for bike share in the RoW, but its these massive wide roads that are like highways that have green boulevards where the sidewalk [normally] is . . . [and the building face] could be like 100m from the RoW, so that's a big problem."[224] Intensification of urban centres should thus start with reorienting the design of the large arterials typical to the suburbs, in order to accommodate human-scaled movement and socialization—space is surely

[220] Schiller, Bruun & Kenworthy, *Sustainable Transportation,* 13.
[221] Andres Duany, Jeff Speck & Mike Lydon. *The Smart Growth Manual.* (New York, NY: McGraw Hill Professional, 2010), 8.1.
[222] Ellen Dunham-Jones & June Williamson, *Retrofitting Suburbia,* 110.
[223] ibid., 110-11.
[224] Sean Wheldrake, interview.

not a problem. By deprioritizing cars, good complete street designs recognize this and rebalance street space and use. Accommodating human-scaled movement first in street design helps re-establish the street as public space, laying the foundation of a strong local economy and public transit system. This promotes spatially efficient transportation by setting off what NACTO calls the virtuous cycle of 'more riders – more service – more street space' that enables transit to be financially sustainable and more frequent. Complete street designs create more room for public transit, green infrastructure, and biking and walking networks, which enhances local economies by making thoroughfares and streets livelier, safer, and more enjoyable public spaces.[225] Reciprocally, when streets become pleasant places more people are more likely to leave their car at home in the first place.[226] In their role to facilitate ease of both local mobility and regional travel by connecting transit users, bike sharing supports and complements complete street designs and the use of streets as public space. Contributing to car modal shift, streets can be friendlier places to socialize with bike sharing, and the associated cycling infrastructure serves to calm traffic on larger streets as well. As bike sharing stations creating points of social convergence, they also dualistically serve as a mobility service station and an anchor for further placemaking within the community. In the end, the complete streets approach benefits automobile drivers as well, as safe infrastructure for multiple transportation modes such as walking, cycling and transit in combination with mixed-use zoning reduces vehicle congestion through modal shift to alternative transportation methods.[227]

5.5.4 TOD Expansion, Cycling-specific Urban Design & the Role of Bike Sharing

To facilitate growth centre density intensification, anchoring TOD to RER stations that interface other express transit such as LRT & BRT can serve to restore the transportation-land use connection in regional growth centres that is so important to the sustainable urban form sought for in New Urbanism and smart growth strategies. Towards this, multimodal complete street designs should be employed to create a livable, human-scaled built environment, where a bike sharing program can serve a central mobility role. While density is a critical factor in bike sharing usage rates, it is not the only factor. Bike Share Toronto manager Sean Wheldrake identified the density, walkability and bikeability as the primary built environment aspects that

[225] NACTO, *Transit Street Design Guide*, 2-3.
[226] Duany, Speck & Lydon, *Smart Growth Manual*, 8.1.
[227] Duany, Speck & Lydon. *The Smart Growth Manual*, 3.10.

determine the success of a bike sharing program. “If you’re in a Dutch city, you’re going to have a lot of cyclists,” he explained. “But if you’re in a Dutch village, you’re still going to have a lot of cyclists, because 50% of the population bikes all the time.”[228] Hence, while density intensification processes will further justify BSSs in Urban Growth Centres over time, the design and built environment of these centres play a critical role. In her review of bike sharing program impacts and processes, Ricci found that increasing overall cycling rates can be effectively facilitated by “establishing bike sharing as a dense network in areas with intense social, cultural, leisure and economic activities, and in connection with public transport networks.”[229] Smart growth and new urbanist planning strategies such as TOD can set the foundation of a successful bike sharing program by re-establishing a connection between transportation and land use through increased density, effective transit, complete streets and mixed-use zoning. Successful land use mixes identify dynamic synergies of supportive uses to collectively generate local economic interaction and enhance the liveliness of a place. A mixed-use synergy—where residential attracts retail, retail supports offices, offices anchor restaurants, and restaurants attract residential—constitutes an ideal operating environment for BSSs.[230] In the context of such regional growth centres, increased bicycle modal share can serve to enhance human-scaled movement and environments, local economic activity, and aid in the achievement of broader new urbanist smart growth, TDM and transit goals. If employed within a coordinated intervention package, BSSs can prove to legitimize expansion of the TOD built form beyond the traditional pedestrian shed while serving as an effective first/last mile solution to RER. The combination of these three—bike sharing, TOD, and integration with RER—yields a sum of benefits to all aspects that are far greater than any one of its parts.

[228] Sean Wheldrake, interview.
[229] Miriam Ricci, “Bike Sharing: Review of Evidence,” 36.
[230] Ellen Dunham-Jones & June Williamson, *Retrofitting Suburbia*, 109.

Employing an urban design approach in TODs that more explicitly provides for cyclists' needs can significantly improve cycling rates compared to the current TOD design standards based on the needs of pedestrians. As noted earlier in this paper, Reid Ewing et al.'s analysis of five TODs appears to show only minor increases in TOD cycling modal share relative to the U.S. national average of 1%. While four out of five TODs studied do exceed the U.S. national bike modal share average, Table 3 shows the average bike modal share across all TODs as only 2.5%. Ewing et al. further argued that for planning purposes, "it is safe to assume a small bike mode share for any planned TOD. It will not have much effect on overall vehicle trip and parking generation whether you assume a 1% bike mode share, the national average, or a 4% bike mode share, the highest for our five TODs."[231] Yet, while Fruitvale's 4.3% bike modal share is a fourfold+ increase over the U.S. national average, this modal share is dwarfed by the bicycle modal share of a city such as Portland, where a 2009 city-wide sample showed 6% of workers cycle. This difference serves to suggest that TOD designs can do better at promoting cycling as a mode of transportation.

Average Mode Shares for TODs Studied.

TOD	Count	Mode shares					
		Walk	Bike	Bus	Rail	Auto	Other
Redmond	1981	18.9%	1.7%	13.0%	NA	64.9%	1.5%
Rhode Island Row	8451	16.6%	0.3%	9.3%	27.2%	42.5%	4.0%
Fruitvale	16,558	28.3%	4.3%	15.2%	26.1%	23.0%	3.1%
Englewood	14,073	19.2%	3.8%	3.3%	13.6%	59.7%	0.2%
Wilshire/Vermont	11,043	27.4%	2.2%	21.1%	20.1%	25.9%	3.4%
Simple Averages	NA	22.1%	2.5%	12.4%	21.8%	43.2%	2.4%

Table 3. Source: Ewing et al. (2017).

Including BSSs as a fundamental design aspect of Urban Growth Centres can promote higher cycling rates in Urban Growth Centre TODs, but cycling-supportive urban design is also a necessary component. TOD transit stations are traditionally accessed by what Griffin and Sener call "the three primary surface transportation modes." The most common, walking, is limited by distance. Next, the personal automobile, is problematic because the space needed for access and parking increases station cost significantly, and importantly, this mitigates the objectives of TOD to begin with. Third is cycling, of which Griffin and Sener argue "promises the sustainability benefits of walking while extending the effective access shed to a distance of 2 to 5km."[232]

[231] Reid Ewing et al., "Trip and Parking Generation at Transit-Oriented Developments*,"* 73.
[232] Greg Phillip Griffin & Ipek Nese Sener. "Planning for Bike Share Connectivity to Rail Transit," *Journal of Public Transportation 19:2* (2016): 2.

Moreover, Forsyth and Krizek suggested that in retrofitting existing urban areas for more sustainable travel, especially areas with previously lower densities, it is unrealistic to think that walking will be the whole solution. "A more holistic approach would involve cycling; a more comprehensive urban design strategy would make that experience delightful as well as safe." In acknowledging that cyclists have substantially different experiences and needs than both pedestrians and motorists, Forsyth and Krizek argue that "urban design needs to stretch its repertoire to acknowledge that; pedestrian-, auto- and even transit- oriented design is insufficient."[233] Forsyth and Krizek's approach entails focusing on more than just the safety of cyclists, but the quality of the cycling experience as well. For example, in considering cycling experience, Forsyth and Krizek argue for providing routes where appropriate that are "uncomplicated enough to permit cyclists to spend time viewing the scenery," as well as allowing for more social interaction on cycle tracks and at destinations by creating space for groups of cyclists to park and interact "through well-designed path pull offs, parking and alternative slower-paced routes."[234] Accommodating cyclists of all skill levels is also important, as well as providing "opportunities for cyclists to modify the environment over time—through a planning process, by creating movable parts, or via programming."[235] A set of cycling-specific urban design guidelines provided by Forsyth and Krizek is shown in Table 4 on the following page.

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[233] Ann Forsyth & Kevin Krizek. "Urban Design: Is there a Distinctive View from the Bicycle?" 534, 546.
[234] Forsyth & Krizek, "Urban Design: Is there a Distinctive View from the Bicycle?" *Journal of Urban Design 16:4* (2011): 532.
[235] ibid., 539, 546.

	Key issues	Design recommendations
Part 1: Networks and layouts	Create a seamless network without discontinuities. Provide options for those wishing to go at different speeds—(a) faster commuters or Class A recreational cyclists vs. (b) slower Class B and C cyclists and those who wish to do more sightseeing or ride in sociable groups. Connect to other modes, primarily transit.	1. Provide a hierarchy of cycling streets, linking key urban places, that overlaps but is probably not the same as the hierarchies for pedestrians and motorists. Make this legible through physical and other cues. 2. Conceive of slightly separate networks for what in the US context has been referred to as Class A versus B and C riders, with the former sharing vehicular roadways more often and the latter having separated bicycle paths or sharing paths with pedestrians, skateboarders, etc.
Part 2: Facilities	Create a mix of levels of separation appropriate to the place in the network and types of cyclists: separated completely, shared with cars, shared with pedestrians and shared with both. Decide how wide to make separated or shared lanes depending on volume or riders, need for sociable riding, and so on. Design the separation, if there is one (e.g. raised strip, striping, bollards, planting). Detail how separated paths meet shared routes at intersections and crossings (with implications for accidents). Use other strategies to avoid accidents at intersections. Provide clear signage and signals. Use space effectively for parking. Prevent visual and physical clutter in the pedestrian environment. Provide appropriate levels and forms of lighting.	3. Space the high-speed/bicycle-arterial part of the grid more closely than is typical for motorists. 4. Design carefully for potential conflicts on shared paths or lanes (auto/cycle or pedestrian/cycle). These will likely require additional width. 5. Duplicate facilities may be needed on key routes (e.g. on street lanes for Class A and B cyclists and off street paths for Class B and C folks). 6. Match detailing of adjacent buildings and landscape to cycling speed, considering visual quality and social interactions along with safety (see below for more on this topic). 7. Avoid making intersections too visually complex given that adding substantial cycling capacity will do that anyway through added striping, signals, and signs. 8. Provide for informal bicycle parking (e.g. poles), small-scale formal parking (e.g. racks), and large-scale parking lots as appropriate. In doing this it is important to consider the needs of pedestrians for free movement. 9. Design smaller-scale parking to perform multiple functions (e.g. as public art, bollards, tree protectors) in order to reduce the perception of visual clutter. 10. Provide lighting that caters to cyclists in terms of height and the area illuminated (e.g. cyclists may need clearly lit road edges while pedestrians need lit paths and motorists the central part of the road carriageway). 11. Illuminate off-road paths that are meant to be used at night and clearly indicate those that will not be lit (considering their place in the network).
Part 3: Processes	Represent all types of cyclists in the urban design process. Use measurement and analysis tools that take into account the cyclist's experience. Allow for evolution over time. Acknowledge expertise from transportation and urban design.	12. Actively encourage participation of cyclists who vary in skill-level, age, income and cycling purpose because their experiences will differ. Participation would be in planning processes and also in changing the environment over time. 13. Perform at least some analyses from a cyclist's view. Appropriate tools could include 'windshield' surveys using a clip on microphone, urban design checklists, photovoice or day with a camera exercises, neighbourhood tours, crime-prevention through environmental design (CPTED) assessments and map-based analyses using the cycling network as the base network, e.g. accessibility assessments.
Part 4: Detailed design	Consider the experience of the built environment at a speed beyond the pedestrian but slower than the auto (or transit). Provide for the physical and social needs of the cyclists, through details such as lighting and parking, in a way that contributes to overall urban design, e.g. legible at cycling speed but also comprehensible for pedestrians.	14. Consider several urban design dimensions that vary in terms of the speed at which they are experienced such as complexity, texture. 15. Consider how the environment is experienced at different cycling speeds, e.g. low speed on mixed routes vs. higher speeds on separated paths. This will have implications for the level of complexity and scale of urban design elements. 16. Create visually interesting environments for cyclists but do not clutter the pedestrian or vehicular realms. Consider artful detail.

Table 4. Cycling-specific Urban Design Guidelines. Source: Forsyth & Krizek (2011).

TODs that combine BSSs and quality cycling-specific design considerations no longer need to be constrained by the typical pedestrian shed of its associated transit station. In addition to cycling-specific design, complete station designs in tandem with BSSs can effectively bypass the identified barriers to C-T integration. This can extend the catchment area of RER and rapid transit stations beyond pedestrian sheds at a much lower cost than feeder buses or park-and-ride facilities.[236] Using this approach can attract new and otherwise inexperienced cyclists to the C-T option, and effectively induce demand from the majority 'interested but concerned' group that constitute 60% of most city populations. The general consensus on the pedestrian shed size of a given transit station, shown in Figure 25, is a radius generally between ¼ - ½ mile (0.4 – 0.8km), but upwards of 1 mile (1.6km) depending on a number of factors. This range is primarily contingent upon the scale and quality of transit service, and the quality and comfort of walking route conditions (i.e. direct routes, safe and comfortable sidewalks and crosswalks, access to storefronts and shade, etc.).[237] Biking shed distances are of course larger than pedestrian sheds—up to a radius of 3 miles (4.8km) according to the US Federal Transit Administration (FTA) and the Mineta Transportation Institute, although some argue bike shed sizes are even greater—up to 25km.[238] Yet for the purposes of the

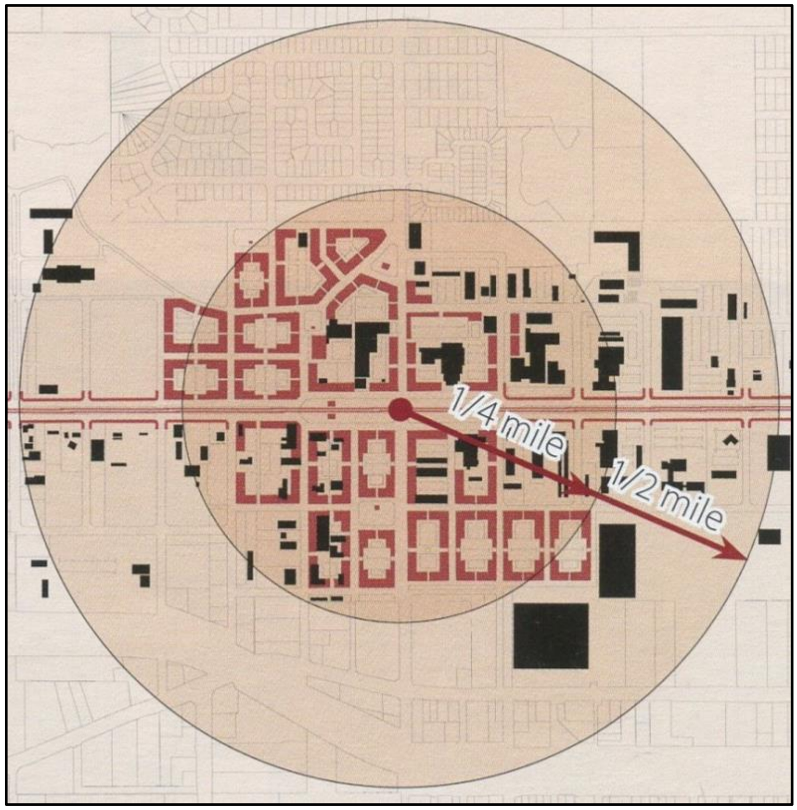

Figure 25. Conventional pedestrian shed size. Source: Tachieva (2010), 154.

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[236] John Pucher, Ralph Buehler, Mark Seinen, "Bicycling Renaissance in North America," 467.
[237] "How far will Transit Users Walk? How Large can a Transit-Oriented Development be?" TDM Encyclopedia – Transit Oriented Development, Victoria Transport Policy Institute, last updated 18 July 2017, http://www.vtpi.org/tdm/tdm45.htm.
[238] Federal Transit Administration, *Manual on Pedestrian and Bicycle Connections to Transit,* prepared by Transportation Research & Education Center (TREC), Portland State University (2017), 13. Url:

GGH, the *Transportation Tomorrow Survey*, a cooperative local and provincial government effort to collect urban travel information in the GGH, 90% of bike trips in the GGH are within 6.1km (3.8 miles), thus defining Metrolinx's maximum 'bikeable' distance as significantly farther than that of the FTA or Mineta Institute.[239] However, these distances are determined by straight 'crow-fly' measurements, and biking shed distances are contingent upon similar factors as those that influence the elasticity of pedestrian sheds. Ultimately, cyclists are constrained by the existing network of supportive infrastructure; hence the quality, connectivity and safety of cycling infrastructure and facilities not only influence the number of cyclists but also the acceptable distance in which most cyclists would reasonably travel.[240]

As a first/last mile connection, bike sharing users are also constrained by the convenience and availability of locations to drop off and pick up public bicycles. This requires locations to not only be integrated spatially with transit stations, but also distributed at residential and commercial destinations throughout a TOD. "Certainly a way to improve TOD is to integrate bike share stations into the actual TOD design," SFMTA transportation planner Heath Maddox explained. "The idea behind TOD is to give people the ability to live a car-free lifestyle by being

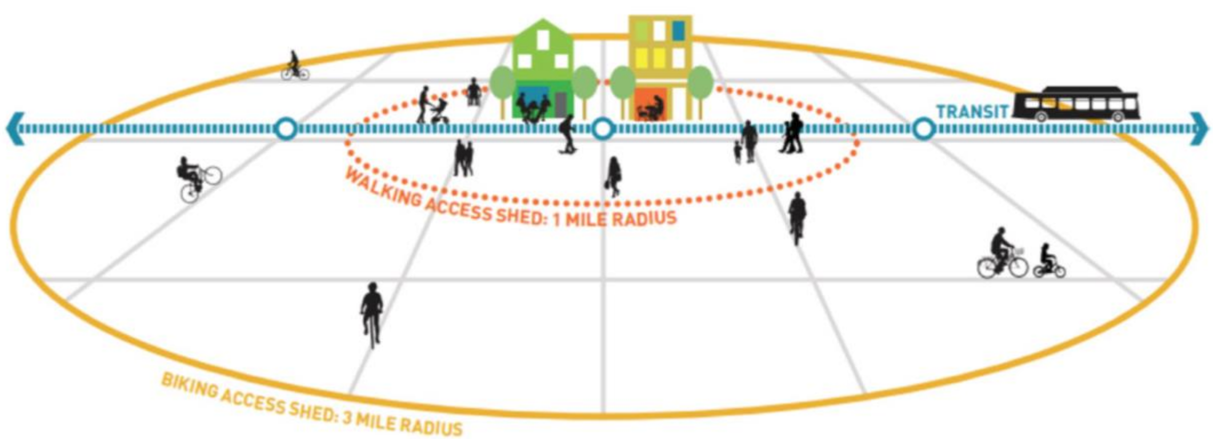

Figure 26. Pedestrian vs. Biking Access Sheds. Source: FTA Manual on Pedestrian and Bicycle Connections to Transit (2017), 13.

https://www.transit.dot.gov/sites/fta.dot.gov/files/docs/research-innovation/64496/ftareportno0111.pdf; Bradley Flam & Charles Rivaplata, "Perceptions of Bicycle-Friendly Policy Impacts on Accessibility to Transit Services: The First and Last Mile Bridge," Report 12-10, *Mineta Transportation Institute* (2014), 40; Schiller, Bruun & Kenworthy, *Sustainable Transportation*, 93.

[239] Metrolinx, *Active Transportation Background Paper – Full Report: Technical Paper 1 to Support the Discussion Paper for the Next Regional Transportation Plan*, prepared by Steer Davies Gleave (2015), 55. Url: http://www.metrolinx.com/en/regionalplanning/rtp/technical/01_Active_Transportation_Report_EN.pdf.

[240] Federal Transit Administration, *Manual on Pedestrian and Bicycle Connections to Transit, 14.*

close to transit . . . even if they're not using bike share to take the train to get to work, bike share is still just another option which makes it that much easier to live a car-free life because they don't need a car to make that other trip, even where they don't need the transit line."[241] Precedent for integrating BSS with development is found in some forward-thinking TOD planning in design out of Charlotte, North Carolina; where developers along LRT lines purchased BSS stations and incorporated them within new residential developments.[242] In a sufficiently mixed-use TOD environment, such an approach would not only greatly improve connectivity to transit but also accessibility to nearby goods and services, allowing BSSs to aid in the facilitation and development of self-sufficient local economies that "retains wealth and saves energy to a degree that can dwarf other sustainability efforts."[243] While current TOD planning practice generally considers a transit station's pedestrian shed as the TOD's spatial scope, increasing ridership by enhancing the cycling environment and implementing BSSs can provide an acceptable foundation for using a biking shed as the standard TOD delineating factor, as shown in Figure 26. This would thereby increase the size of TODs from a maximum of 1.6km to a minimum of 4.8km, and further expand smart growth and new urbanist designs and their associated benefits into previously sprawling suburban regions.

With suburban areas and Urban Growth Centres as the target for RER, rapid transit, and mobility hubs, TOD is a necessary component to both Urban Growth Centre density targets as well as transit ridership. In this context, an integrated regional transit approach that applies a coordinated package of transit-integrated BSSs and complete streets to TOD areas throughout Urban Growth Centres can aid in New Urbanist and Smart Growth retrofits to suburban sprawl. BSSs can also seamlessly support RER with first/last mile services and facilitate local mobility, making transit in the GGH more effective than driving a car. Bike sharing stations can dually be amenities of mobility as well as placemaking anchors for re-envisioning streets as public spaces, while cycling infrastructure calms traffic and facilitates human-scaled movement and more local economic engagement. Deploying bike sharing stations with residential mixed-use developments in TODs can also promote the expansion of TOD areas from beyond the typical 0.8-1.6km

[241] Heath Maddox, interview.
[242] Federal Transit Administration, *Manual on Pedestrian and Bicycle Connections to Transit*, 74.
[243] Andres Duany, Jeff Speck & Mike Lydon. *The Smart Growth Manual.* (New York, NY: McGraw Hill Professional, 2010), 3.7.

pedestrian shed to the larger 4.8-6.1km cycling shed. These efforts can be effective in generating a positive feedback loop for inducing significant cycling demand from the majority 'interested but concerned' demographic group, popularizing cycling to levels not yet seen amongst suburbs.

6. Conclusion

The possible outcomes of integrating BSS with high-order transit such as the forthcoming GO RER offers a glimpse at changing our suburban transportation reality. As this paper argues, taking a regional approach to transit-integrated bike sharing can make a significant impact on people travel throughout the region and its localities, and transform land use planning to mitigate suburban sprawl. While integration for regional transit reasonably starts with fare integration and cycling-supportive station design, newly emerging MaaS systems can serve as the basis for a complete, seamless integration between BSSs and fixed-route transit systems. Implementing a coordinated package of bike sharing and dedicated cycling infrastructure in Urban Growth Centres can provide significant contributions to complete streets that accommodate human-scaled movement first, help re-establish the street as public space, are safer and more enjoyable, and lay the foundation for effective transit networks where previously not possible. A coordinated package of cycling infrastructure and BSSs can significantly increase cycling rates, contribute to station integration, and improve the cycling-transit interface generally. This package is also a crucial element to local design contributions, where it is argued BSSs should be considered as a fundamental design element to Urban Growth Centres in order to facilitate New Urbanist design and improved TOD. This approach aims to connect people with their region and with each other, and allow residents more opportunities to enjoy their journeys through a level of engagement with their urban environment not possible in the confines of a car. A region that adopts this approach can successfully mitigate, retrofit and indeed repair sprawl; and in the process, create a public environment that people choose over the private confines of their car and home.

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