The Integration of Green Infrastructure and Intensification, the Case of Greater Toronto Area

by

Sara Saboonian

A thesis

presented to the University of Waterloo

in fulfillment of the

thesis requirement for the degree of

Doctor of Philosophy

in

Planning

Waterloo, Ontario, Canada, 2024

© Sara Saboonian 2024

Examining Committee Membership

The following served on the Examining Committee for this thesis. The decision of the Examining Committee is by majority vote.

External Examiner	Jennifer Foster Professor, York University
Supervisor(s)	Jeff Casello Professor, University of Waterloo
Internal Member	Pierre Filion Professor Emeritus, University of Waterloo
Internal Member	Jeremy Pittman Professor, University of Waterloo
Internal-external Member	Mike Stone Professor, University of Waterloo

Author’s Declaration

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

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

Abstract

This dissertation explores the integration of green infrastructure (GI) and urban intensification within the Greater Toronto Area (GTA). It investigates how blending GI with intensification can create sustainable urban environments amidst rapid urbanization. The study begins by examining the challenges posed by suburban development, characterized by low density, automobile reliance, and significant environmental impact. It highlights the potential of sustainable planning models, particularly GI and intensification, to address these challenges through compact settlement, public transit promotion, and the development of green spaces.

The research identifies the common sustainability goals of GI and intensification, despite their different approaches and strategies. It outlines the historical evolution of these models and the emergence of environmental concerns that shaped contemporary GI policies. The dissertation further categorizes the goals and strategies of GI and intensification into urban life, urban efficiency, and urban environment, providing a detailed comparison and identifying opportunities for their integration.

Through a mixed-methods approach, including case studies of Downtown Mississauga and Markham Centre, literature review, interviews, and direct observations, the research explores the GI design guidelines in areas undergoing intensification. It emphasizes the importance of connectivity in both GI and pedestrian networks to enhance urban sustainability and livability. The study proposes design guidelines for integrating GI and pedestrian connectivity in intensified urban areas, aiming to improve ecosystem services, walkability, and the overall appeal of the built environment.

The findings contribute to the body of knowledge on sustainable urban planning by offering practical solutions for blending GI and intensification. The proposed design guidelines are intended to support policymakers, urban planners, and designers in creating multifunctional urban spaces that balance high-density development with the preservation and enhancement of GI. This dissertation underscores the significance of integrating natural and built environments to achieve resilient and livable cities.

Acknowledgements

I acknowledge that I conducted this research on the traditional territory of the Neutral, Anishinaabeg, and Haudenosaunee peoples. Moreover, the campus of the University of Waterloo, where this research took place is on the Haldimand Tract, the land granted to the Six Nations that includes six miles on each side of the Grand River.

My PhD program coincided with an amazing lifetime event, the birth of my son, as well as challenges, including Covid-19 pandemic, and retirement of my academic supervisor. I experienced a mix of positive experiences and difficulties, as well as meeting many amazing people during the process. I would like to take a step back and personally thank each and every individual who has helped me during this journey. First and foremost, I would like to thank myself for being resilient and persistent, for not giving up, for growing as a person, and for accomplishing something truly meaningful.

I would like to express my deepest gratitude to my supervisor, Professor Jeff Casello, whose unwavering guidance, insightful expertise, and exceptional commitment have been instrumental in bringing this thesis to the finish line. Despite his demanding responsibilities, he dedicated considerable time and effort to help me refine my work, organize its structure, and clearly articulate my contributions. His invaluable support and encouragement in every imaginable way have been pivotal throughout this journey. I also wish to acknowledge my former supervisor, Professor Pierre Filion, for his involvement in my research and the foundational support he provided during the inception and research conduction stages of my doctoral studies. Both of their contributions, in their own ways, have shaped this thesis, and I am deeply grateful for their respective roles in this process.

I would also like to sincerely thank my dissertation committee members Professor Jennifer Foster, Professor Mike Stone, and Professor Jeremy Pittman for reviewing my thesis and providing valuable comments and guidance for improving of this research. I would also thank my professors in the University of Minnesota, twin cities — Richard Strong, Blaine Brownell, Julia Robinson, Mary Guzowski, and Daniel Handeen — for teaching me the fundamentals of sustainability research and providing academic support throughout the years.

I would like to show my deepest thankfulness to my lovely son, Dario Yazdani. As the only family member from generation Alpha, Dario has helped me gain self-knowledge, which has supported all aspects of my life, including my education and career. I would also like to express my deepest gratefulness to my dear parents, Mohammad Bagher Sabounian and Soudabeh Hassani for providing me with all subjective and objective support and raising me in a way that I could finish my PhD. I would also thank my dear spouse, Farzad Yazdani, who inspired me from the inception of this journey to its end and graciously provided me with his amazing support. I would also thank my dear brother, Sina Saboonian who not only supported me in my PhD journey but also in all my life journeys. I am also grateful to my dear in-laws, Maryam and Hossein Yazdani who helped us complete our researches. I would like to thank my late grandfather, Mohammad Taghi Hassani, who introduced social science to me in my childhood years. I would like to also thank my uncles and aunts Sassan Hassani, Parisa Hassani, Abdolreza Salehi, Mehri Yekta, and Abdollah Sabounian for supporting me both academically and non-academically. Finaly, I would like to remember the late and great Amoo Abbas, who showed me how to be humble and a loving human being.

I would also like to express my gratitude to my amazing family friends — Nina Pulver and Seth Koplowitz — who wholeheartedly stood beside me and supported me emotionally and professionally in any imaginable way to finish my PhD program. I would also like to thank my fantastic friends — Saeed Khosravani and Mojgan Ghare — for standing beside me from the beginning of my program and supporting me cross the finish line. I would also like to thank my colleague/friends Rafael Harun, Pedram Fard, Katherine Laycock, Xing Su, and Matthew Quick for supporting me and making this journey a memorable experience for me.

Last but not least. I would also thank my amazing friends, Sadaf Jafari, Ghazal Ghods, Hamia Aghaiemeybodi, Farhad Aghaiemeybodi, Afsaneh Ebrahimi, Afsoon Ebrahimi, Marjan Kimiaghalam, Lisa Lotteme, Behrang Fakharian, Shima Moradi, Mojdeh Youssefi, Sardar Farrokhi, Rosa Abili, Arsalan Niksar, Hamid Khandan, Hadi Saffarian, Elena Mokhtari, Pantea Abtahi, Mona Ebrahimi, Shooresh Fatollahi, Elham Ayati, Elham Shahrabi, Zoya Alizadeh, Afsheen Ebrahimi, Hanieh Pourmand, Nima Noorinasab, Pardees Ghajar, Elnaz Ziaee, Roushanak Navvab, Sara Fana, and Payam Baghaee Moghaddam for their great support.

Dedication

I dedicate this research to future generations, including my beloved son, Dario Yazdani, with the hope of contributing to a better future — socially, economically, and environmentally.

Table of Contents

Author's Declaration iii

Abstract iv

Acknowledgements v

Dedication vii

List of Figures xiv

List of Tables xvi

Chapter 1 Introduction 1

1.1 Context 1

1.1.1 Sustainability Planning Models: 1

1.1.2 Intensification: 1

1.1.3 Green Infrastructure 2

1.1.4 Intensification and GI Issues 3

1.2 Problem Statement and Motivation: 4

1.3 Area of Focus 6

1.4 Problem Statement 7

1.5 Objectives and Research Questions 8

1.6 Thesis Outline 11

Chapter 2 Literature Review 13

2.1 Curbing Sprawl 13

2.1.1 New Urbanism 14

2.1.2 Smart Growth 14

2.1.3 Compact City 15

2.2 Intensification 15
2.2.1 Intensification Goals 16
2.2.2 Intensification Policies 16
2.2.3 Synergy of Intensification Policies and Strategies 17
2.3 The Categorization of Intensification Strategies 17
2.3.1 Urban Life Goals 18
2.3.2 Urban Efficiency Goals 20
2.3.3 Urban Environment Goals 21
2.4 Green Infrastructure (GI) 21
2.4.1 Historical Origins of the GI Concept 22
2.4.2 The Emergence of Environmental Concerns 22
2.4.3 Evolution of the GI Concept 23
2.4.4 The Evolution of GI Policies and Strategies 24
2.5 Categorization of GI Goals and Strategies 28
2.5.1 Urban Life Goals 29
2.5.2 Urban Efficiency Goals 31
2.5.3 Urban Environment Goals 32
2.6 Comparing GI and Intensification Strategies 33
2.7 UPOSs as Common Space for Developing GI and Intensification 37
2.8 Conclusion and Lessons Learned 37
Chapter 3 Methodology 39
3.1 Designing a Mixed Methods Approach 39
3.1.1 Worldviews and Research Questions 40

3.1.2 Research Questions and Mixed Methods 41
3.2 Case Studies 44
3.2.1 Overview 44
3.2.2 Intensification in Southern Ontario 45
3.2.3 Downtown Mississauga 49
3.2.4 Markham Centre 53
3.2.5 Comparing the Planning Context of the Case Studies 57
3.3 Targeted Literature Review and Systematic Search 57
3.4 Record of the Planning Documents 62
3.5 Interviews 64
3.6 Direct Observations 69
3.7 Data Analysis 72
3.8 Design Proposals 74
3.9 Summary of the Methods 76
Chapter 4 Discussions and Findings 77
4.1 Previous Efforts for Blending GI and Intensification 77
4.1.1 Including GI in Compact City 78
4.1.2 Co-developing GI and the Compact City 79
4.2 Lack of Design in Previous Efforts for Blending GI and Intensification 80
4.2.1 The Potential Blending of GI and Intensification through Connectivity 80
4.2.2 GI Connectivity 81
4.2.3 Intensification Connectivity 83
4.2.4 Similarity between GI and Pedestrian Connectivity 85

4.2.5 Design Opportunity for GI and Pedestrian Connectivity 86
4.3 Finding Common Ground between GI and Intensification 87
4.3.1 The need for integrating GI and intensification 87
4.3.2 Current Approach of the Literature for Integrating GI and Intensification 89
4.3.3 Similar Spatial Objectives of GI and Pedestrian Connectivity 90
4.3.4 Means of Blending GI and Pedestrian Connectivity in Intensification 91
4.4 Barriers to Developing GI and Pedestrian Connectivity in Intensified Areas 93
4.4.1 Summary of the Interview Findings 93
4.4.2 The Negative Impact of Large-size Urban Blocks on Pedestrian Connectivity 97
4.4.3 The Negative Impact of Car-dominated Roads on Pedestrian Connectivity 98
4.4.4 The Negative Impact of Large-size Urban Blocks on GI Connectivity 99
4.4.5 The Negative Impact of Car-dominated Roads on the GI Connectivity 100
4.5 Providing GI and Pedestrian Connectivity on an Urban Scale in the Case Studies 101
4.5.1 Current Provision of GI Connectivity on an Urban Scale 101
4.5.2 Current Provision of Pedestrian Connectivity on an Urban Scale 106
4.6 Finding Space for Blending GI Connectivity and Pedestrian Connectivity in Intensified Urban Areas 111
4.6.1 Arterial Roads and Highways (ARHs) 114
4.6.2 Collectors and Local Roads (CLRs) 115
4.6.3 Underutilized Lands (ULs) 116
4.6.4 Natural Corridors (NCs) 121
4.7 Planning and Implementation Gaps 123
4.7.1 Barriers to GI implementation in Municipalities 124

4.7.2 Design-based Gaps to Integrate GI and Pedestrian Networks 125
4.7.3 Financial Barriers to Integrate GI and Pedestrian Networks 129
4.8 Addressing the Identified Gaps by Blending GI and Pedestrian Connectivity in UPOSs 130
4.8.1 A GI Typology for UPOSs 131
4.8.2 Demand for Ecosystem Services in UPOSs 132
4.9 Design Proposal- The Restoration of Mary Fix Creek in Mississauga Centre 142
4.9.1 Site Description 142
4.9.2 Needed Ecosystem Services 147
4.9.3 Design Strategies 148
4.9.4 Proposed Structures 149
4.9.5 Proposed Corridors 150
4.9.6 Proposed Ecosystem Services and Avoided Disservices 151
4.9.7 Proposed GI and Pedestrian Connectivity 153
4.10 Exploring the Transferability of the Proposed Method 154
4.11 Conclusion and Future Work 155
Chapter 5 Conclusion 157
5.1 Summary 157
5.2 Policy Recommendations 162
5.3 Contribution 163
5.4 Future Research 166
References 168
Appendix A Glossary of Terms 195
Appendix B 199

Markham Questionnaire 199

Mississauga Questionnaire 201

List of Figures

Figure 3-1 Overview of the research design 42
Figure 3-2 Boundaries of Downtown Mississauga and Markham Centre, and their locations with respect to other UGCs near Toronto. 48
Figure 3-3 Map of Downtown Mississauga as per Downtown21 masterplan (City of Mississauga, 2010) 50
Figure 3-4 Progression of development in Downtown Mississauga, (a) 2004 and (b) 2023 (Google, 2023). 51
Figure 3-5 Location of the green spaces in Downtown Mississauga (City of Mississauga, 2010). 52
Figure 3-6 Expanding the boundaries of Markham Centre between 1994 and 2020. 54
Figure 3-7 Systematic search steps taken in this research. 59
Figure 4-1 Different types of connectivity: (a) structural connectivity, where two patches are connected via a corridor, (b) potential connectivity, where organisms are able to move between patches, and (c) functional connectivity, where the movement of species is confirmed by observation. 82
Figure 4-2 Example of crossings over the Rouge Valley without interactions with the surroundings. Top: highlighting the long walk between two destinations, bottom; pedestrian view over the bridge 98
Figure 4-3 distribution of parks around the outer ring of Downtown Mississauga. 103
Figure 4-4 Location of parks, buffer zone (edge parks), and other green spaces in Markham Centre (City of Markham) 104
Figure 4-5 Street Networks proposed by the current masterplans for Downtown Mississauga 9top) and Markham Centre (Bottom) (City of Mississauga; City of Markham) 107
Figure 4-6 Street grid and GI elements in Mississauga (City of Mississauga). 108
Figure 4-7 Comparing 5- and 15- minutes walking distances in Mississauga and Markham Centres, respectively (City of Markham, 2020; City of Mississauga, 2010). 110
Figure 4-8 activating frontages in Downtown Mississauga (City of Mississauga, 2010) 115
Figure 4-9 retrofitted surface parking in Downtown Mississauga (Google Earth, 2024) 117
Figure 4-10 pervious alley covered by permeable interlocking tiles 118
Figure 4-11 Scholar's Green in Downtown Mississauga (Google Earth) 122
Figure 4-12 The site in Downtown Mississauga used for the design proposal 143
Figure 4-13 Example photos collected during the virtual and in-person site visits. 146
Figure 4-14 Comparison between the masterplan (top) and developers' plans (bottom) (www.mcitycondos.com) 147
Figure 4-15 The proposed structures and its connectivity with the surrounding neighbourhood. 150

Figure 4-16 Detailed view of the two proposed corridors. 151
Figure 4-17 the need for delivering ecosystem services and avoid disservices..... 153
Figure 4-18 Connectivity for the proposed GI and pedestrian networks. 154

List of Tables

Table 2-1 Comparison between Intensification and GI strategies. 35
Table 3-1 List of the reviewed documents 66
Table 3-2 List of Interviewees and their occupations 67
Table 3-3 Example interview questions and the recorded answers. 68
Table 3-4 Example of recorded field notes 71
Table 4-1 Description of the Categories of UPOSs. 113
Table 4-2 Spatial Classification and Description of GI elements 136
Table 4-3 Demand for Ecosystem Services in the UPOSs 138
Table 4-4 Collecting data about the site from the interviews 143

Chapter 1
Introduction

1.1 Context

Amidst rapid urbanization, there is an increasing need to explore the potential of novel tools for the creation of sustainable urban environments. Suburban development, characterized by near universal automobile reliance, overall low density, and rigid land-use specialization, has been the dominant form of development across North America for the past seventy years (Filion, 2003; Saboonian & Filion, 2019; Xu, 2017). However, the suburban planning model has been increasingly criticized for its significant infrastructure requirements (stemming from dispersed development), lack of urban accessibility for all social groups, and damage to the natural environment due to heavy and inefficient reliance on automobile use.

1.1.1 Sustainability Planning Models:

Over the past forty years, urban planning models that can maintain social cohesion, constrain the use of resources, promote competitive growth, and strengthen participation, have all been advanced under the umbrella of sustainable development. Different sustainable planning models have attempted to address their objectives by incorporating various planning tools, such as compact settlement, public transit promotion and green city development (Barresi, 2018; Batty, 2009; Lobaccaro & Frontini, 2014). Green infrastructure (GI) (i.e., A network of natural and semi-natural spaces, features, and systems, such as parks, green spaces, wetlands, and green roofs in urban areas) and intensification (i.e., The process of increasing the density and diversity of the built environment in urban areas, often implemented as a solution to urban sprawl) are two examples of sustainable planning models that offer solutions to the consequences of dispersion. While these two models pursue different approaches with differing strategies, they have similar sustainability goals (Tappert et al., 2018).

1.1.2 Intensification:

‘Intensification’ and other interchangeable concepts, such as ‘densification’, and ‘consolidation’, are used to describe development and redevelopment of cities where infrastructure is already in place. Intensification promotes the compact built environment, increased population density, mixed-use lands (i.e., An urban planning concept that integrates a mix of residential, commercial, and recreational uses within the same area), as well as public transit and non-motorized transportation, (i.e. ‘active transportation’) (An & Gu, 2018; Brunner & Cozens, 2013; Vecchio & Arku, 2020). In North America,

local and regional policies have made use of intensification to reduce the outward expansion of cities and to conserve natural land and resources. (Vecchio & Arku, 2020).

Intensification addresses the economic, environmental, and social aspects of urban development. It promotes economic growth by utilizing services, buildings, and transportation in current urban areas, which reduces the capital cost of urban infrastructure (Williams, 2004). It also serves the environment by restricting suburban sprawl (i.e., low-density, car-dependent expansion of urban areas into undeveloped land, leading to inefficient land use and environmental degradation), which protects natural areas and reduces the development pressure on environmentally sensitive areas and farmland (Searle & Filion, 2011). Additionally, it enhances social qualities by promoting affordability, accessibility, housing choice and social activities (Forsyth et al., 2007).

1.1.3 Green Infrastructure

Green Infrastructure (GI) is defined as a network of natural and semi-natural features, which are essential for human health and well-being. GI planning is based on historical green movements, such as the Garden City, and contemporary environmental approaches, such as greenway planning. GI is intended to enhance the quantity and quality of green spaces, and increase their overall continuity (Benedict and McMahon, 2006). In an urban context, a GI network refers to strategically planned networks of natural and semi-natural areas, interacting within an urbanized environment that are designed and managed to deliver a wide range of ecosystem services (Staccione et al., 2022). Ecosystem services (i.e., The benefits that humans derive from ecosystems, including provisioning services, regulating services, supporting services, and cultural services) are the benefits provided by GI for humans. GI measures, such as parks, gardens, wetlands, and green roofs provide a range of ecosystem services to urban communities, including air and water purification, climate regulation, biodiversity conservation, and recreational opportunities, and are increasingly recognized as an essential component of urban planning (Benedict and McMahon, 2006).

GI and related concepts such as Low Impact Design (LID), an urban development approach that aims to manage stormwater runoff at the source, using green infrastructure techniques and nature-based solutions to reduce its negative impact on urban areas, and Nature-based Solutions (NBS) (i.e., Design approaches that intentionally use natural processes and elements to address environmental and urban challenges), are recognized as valid sustainability planning models, which integrate social, environmental, and economic benefits for improving urban resiliency. As such, they appear in a variety of research areas, such as health, environmental studies, urban planning and design, economics, and technology (Andersson et al. 2019).

1.1.4 Intensification and GI Issues

Despite the growing interest in GI planning, the actual implementation of GI in cities often faces a number of challenges, including lack of knowledge about GI, various technical issues that create barriers to efficient use, and budgetary constraints. Developing design guidelines for GI requires knowledge across multiple fields, including (but not limited to) economics, climate, species ecology, and ecosystem services. For example, the guidelines for selecting species in GI depends on the specific ecology of differing locations (Kumar et al., 2019; Zuniga-Teran et al., 2020). Consequently, there is a dearth of design guidelines that can mainstream GI in planning processes and provide clear design recommendations, such as the location of GI measures, the type of GI application most appropriate to a given context, and the appropriate species selection for GI practitioners.

Ecosystem services are the benefits provided by GI for humans. They are often categorized as provisioning, regulating, cultural, and supporting services. In research articles on the topic of GI, considerable attention is often allocated to ecosystem services, as a means of developing GI measures. However, this is mostly discussed within the context of urban areas, such as shrinking cities and suburban areas with enormous vacant lands, where GI measures can be developed without the issue of spatial constraints. For urban areas undergoing intensification processes, defining space is crucial (Meléndez-Ackerman et al., 2016; Zhang et al., 2019). There is a dearth of studies offering GI design guidelines for the provision of ecosystem services, conservation, restoration, and development of GI measures in intensification areas with limited open space available. This would include for example, brownfield sites, underutilized land, and existing development.

Additionally, intensification faces difficulties in terms of its capacity to address policies, such as for mixed-use development and walkability (i.e., The measure of how friendly and conducive an urban area is for pedestrian movement). Moreover, although intensification supports sustainability by promoting public transit and active transportation, it creates secondary environmental issues, such as air pollution and natural habitat loss. Intensification processes, such as infill development create pressure on the existing GI, and do not prioritize integrating GI measures within their built environments.

Articles suggest that GI cannot only remediate intensification environmental issues, but also assist in achieving intensification goals, such as infrastructure efficiency and enhancing walkability. GI also promotes mixed-use development by providing recreation spaces and promote physical activity (Batchelor et al., 2016). As another example, there is evidence that incorporating GI networks into pedestrian routes persuades pedestrians to choose active transportation options (Honey-Rosés et al., 2020; Venter et al., 2020).

1.2 Problem Statement and Motivation:

Studies have suggested that future sustainable planning models should create compact and green urban environments by combining high-density lands with attractive green features (Gavrilidis et al., 2017; Ronchi et al., 2020; Vargas-Hernández & Zdunek-Wielgołaska, 2021). However, future cities will face a challenging tension in seeking to balance both livability and compactness of the built environment, because GI and compact city planning models are not aligned in practice (Lehmann, 2014; Mesimäki et al., 2019). The 'compact city', and similar concepts such as intensification, increase the density of built environment to reduce car dependency and improve urban animation. GI development, on the other hand, conserves open spaces to protect, restore and develop natural and semi-natural elements (e.g., trees and permeable surfaces). Intensification ignores the importance of GI for the wellbeing of urban habitats (Hendrigan & Newman, 2017), whereas GI planning frequently does not address the challenges of natural restoration and conservation in areas under intensification (Lehmann, 2014; Tappert et al., 2018).

While the tension between intensification and GI persists in practice, a growing body of research has begun to blend the planning philosophies of GI and the compact city. As an example, Artmann et al. (2019) investigated a possible synthesis between the implementation tools of intensification and GI in order to propose a framework for smart-compact-green cities. This indicator-based framework focused on integrating principles of GI and the compact city, such as multifunctionality (i.e., The ability of a space or system to serve multiple purposes or provide multiple benefits in urban planning) and connectivity (i.e., Physical and functional connections between urban elements, such as green spaces and transportation networks, at different scales and from different perspectives) (Artmann et al., 2019; Hansen & Pauleit, 2014; Szulczewska et al., 2017). However, the proposed framework does not discuss built environment matters, such as the scale of development, urban forms, and design strategies.

GI and intensification seem aligned with respect to policy development, since intensification policies mention green space development, while GI acknowledges the implementation of high-performance approaches in urban areas that have significant spatial constraints. However, the lack of design guidelines in both GI and intensification planning is a barrier to addressing their respective policy goals (Haase et al., 2017; Nilon et al., 2017; Saboonian, 2014).

Providing design strategies is crucial for both GI and intensification as they focus on development and redevelopment of lands. Efforts for blending GI and the compact city strategies have remained theoretical due to the lack of practical design guidelines that integrate them. Blending GI and intensification allows for the simultaneous implementation of their core strategies, and a harmonization of their design guidelines. (Buffam et al., 2022).

This dissertation seeks to address the potential opportunities for synthesizing GI and intensification through providing design guidelines that can support the implementation of both. Recent studies have demonstrated that there is a common ground between GI and intensification regarding their sustainability characteristics, which in turn, suggest their capacity for simultaneous implementation (Heins, 2015). However, blending the sustainability characteristics of GI and intensification, such as multifunctionality and connectivity requires design guidelines that can support GI and intensification strategies concurrently (Artmann et al., 2019; Saboonian & Filion, 2019; Tappert et al., 2018).

In urban environments where development density permits or there are vacant lands for development, the adverse environmental effects of new buildings can be effectively mitigated by incorporating the provision of adjacent green spaces. However, in high-density areas with limited space, this offsetting strategy becomes less plausible due to land scarcity and competition for available parcels. In such scenarios, green spaces and vegetation are more likely to consist of multiple small elements. When these elements form a connected network instead of being sparse and fragmented, they can rehabilitate the natural processes more effectively. Therefore, in intensified urban areas, green spaces should not be approached on a site-by-site basis, but rather with a focus on promoting connectivity. Implementing one large GI project that spans across multiple parcels is more impactful than having equally sized small-scale GI interventions dispersed over smaller parcels.

Comparable to a GI network, a pedestrian network is a structure within an urban space that functions best when comprised of streets, pathways, trails, and other pedestrian infrastructures that are interconnected (Jabbari et al., 2023). The connectivity in pedestrian networks plays a crucial role in creating compact and pedestrian-friendly environments. Pedestrian facilities can easily accommodate GI elements, including green areas with vegetation along pathways, urban parks, streetscapes with tree-lined sidewalks, urban tree canopy, and even environmentally friendly features like pervious pavements. Consequently, achieving connectivity for GI within a compact urban area can be seamlessly accomplished alongside the development of a connected pedestrian network. This integration of green infrastructure and pedestrian networks addresses the challenge of environmental sustainability and enhances the overall livability of intensified urban spaces.

For both GI and intensification, connectivity is a spatial characteristic, which supports other sustainability characteristics, such as multifunctionality. The interconnected network of GI increases the number of GI elements across urban areas while improving their functions. On an urban scale, GI connectivity focuses on creating physical connections between landscape elements, such as green spaces, parks, urban forests, and greenways in order to support biodiversity and ecosystem services (Salata & Yiannakou, 2016). For

intensification, the connectivity between different areas of urban centres supports multiple urban activities. Connectivity in intensification planning focuses on facilitating the movement of people through active transportation (Filion & Saboonian, 2019; Hansen & Pauleit, 2014). Pedestrian connectivity plays a significant role in intensification as walking is an essential physical activity for urban residents and the predominant form of active transportation.

This dissertation argues that using deliberate design strategies to integrate GI and pedestrian connectivity in areas under intensification can contribute to achieving both GI and intensification goals. Pedestrian connectivity and GI connectivity both refer to the idea of creating connections between different elements. This similarity has influenced some studies to discuss pedestrian connectivity through the lens of landscape ecology for improving the walkability of cities (Delso et al., 2019). Leveraging this similarity into practical implementation requires a holistic approach for studying different elements of pedestrian and GI networks, as well as a broader understanding of the interconnected relationship between these two in urban environments. It is important to note however, that both of these areas have been inadequately addressed in the literature. This dissertation studies GI planning, intensification planning, GI connectivity and pedestrian connectivity in areas under intensification to find ways for developing design guidelines that can integrate GI and pedestrian connectivity in areas under intensification. To do so, it applies a mixed methods research approach to selected case studies in Southern Ontario, Canada, one of the leading areas for intensification planning in North America.

1.3 Area of Focus

The southern Ontario, Canada area encompasses Toronto's metropolitan area, also known as the Greater Toronto Area (GTA), together with an outlying collection of large, mid-size, and small cities, which are collectively called the Greater Golden Horseshoe (GGH). Intensification planning in the GTA not only seeks to combat suburban dispersion, but also redirects development from downtown Toronto to a series of other downtown areas in the GGH, called Urban Growth Centres (UGCs). This process is supported by the Province of Ontario, as well as the municipal and regional governments where the UGCs are situated (Caldwell et al., 2022). Intensification planning in southern Ontario is useful to understand and use as case study material due to its complex history of urbanization, its scale of development and diversity of UGCs in terms of size/ development stage, its rapid population growth, the extent and growth of transportation infrastructure throughout the GGH, and its diversity of environmental features (Filion et al, 2021; Lam and Conway, 2018).

1.4 Problem Statement

This dissertation seeks to bridge the existing design gap for integrating GI and pedestrian connectivity in areas under intensification. Orchestration of GI elements as networks is crucial for the provision of ecosystem services, which are vital for human health and well-being. Pedestrian features as networks promote active transportation, which support intensification goals. Blending these two networks has the potential to be particularly useful because their goals are mutually reinforcing, and they are developed in shared urban public open spaces (UPOSs). Accordingly, this dissertation tries to address the design aspects of this integration in three areas of urban/spatial planning, urban design, and multifunctional design. The problem statements of these three are as follows:

1. Spatial Planning

Blending GI and pedestrian connectivity through design requires an understanding of how different elements of GI and pedestrian networks can be integrated in spatial plans in intensification processes, such as plans for repurposing and redeveloping lands. Currently, GI elements are included in urban areas in a piecemeal approach through new development, retrofit and redevelopment projects. There is a lack of a practical spatial approach for creating the network of GI elements on city and multiple neighborhood scales. Meanwhile, pedestrian routes are regularly created in different areas of city centers under intensification. However, creating physical continuity and environmental elements that link to the corridors themselves and *encourage* walking are rarely addressed in spatial plans. Providing spatial plans for GI and pedestrian connectivity simultaneously can be one opportunity to enhance the objectives of both in the context of intensification and GI planning.

2. Design Standards

Urban design standards play a critical role in the integration of GI and pedestrian networks in intensification planning. These standards can create a balance between the density of development and the quality of green space through supporting the movement of pedestrians, the delivery of ecosystem services, and species movements. Urban design standards can provide guidelines for the selection and implementation of GI features such as green roofs, permeable pavements, and rain gardens. Such guidelines have the potential to address the spatial interaction between compact built environments and natural processes, which are missing in existing intensification plans.

3. Multi-functional Design

Due to limited availability, physical space is a valuable commodity in intensified areas. The integrated network of GI and pedestrians needs to perform multiple functions to optimize GI benefits and enhance

walkability. For example, vegetated street verges or boulevards can provide stormwater management benefits and habitat for wildlife. At the same time, they can be designed to provide visual appeal, shade, air filtering and noise reduction, as well as serving as a barrier between car traffic to support pedestrian movement. In areas under intensification with spatial constraints, addressing multifunctionality through design contributes to the provision of ecosystem services by GI, and the enhancement of active transportation by pedestrian networks.

1.5 Objectives and Research Questions

The main objective of this research is the amalgamation of GI and intensification through urban design and spatial planning. It reviews the literature to understand opportunities for blending GI and intensification in planning articles and seeks to find research methods that can leverage these opportunities in urban design and spatial planning. Accordingly, the objectives of this dissertation become threefold, namely:

1. To comprehensively understand the current approach toward GI and pedestrian networks in areas under intensification;
2. Develop a framework for the spatial integration of GI and pedestrian networks, including design tools that can deliver ecosystem services and provide physical environmental features for pedestrians in areas under intensification;
3. Propose design solutions for integrated networks in Urban Growth Centres (UGCs).

To achieve these objectives, the dissertation addresses the following questions:

1. How can GI and intensification be integrated?
    a. What is the evolution of GI and intensification planning in articles?
    b. What are the differences and similarities of GI planning and intensification planning?
    c. What are the shortcomings of research in designing and planning for GI and intensification?
2. What are potentials for integrating GI and intensification?
    a. What is the common ground between the spatial planning of GI and intensification?
    b. What are the previous research approaches for including GI in intensification?
    c. What are the shortcomings of articles that tried to blend GI and intensification planning?
    d. What are the potentials for blending GI and intensification in spatial planning?
3. How can GI and intensification be integrated through urban design and planning?
    a. What are the research methods that can discuss blending GI and intensification?

    b. Which urban areas can be used as case studies for blending GI and intensification?
4. How can GI and intensification be blended through integrating GI connectivity and pedestrian connectivity?
    a. What is the state of intensification and GI planning in southern Ontario?
    b. What are the shortcomings of the intensification approach in Southern Ontario?
    c. What is the state of walkability in areas under intensification in Southern Ontario?
    d. What are the barriers to developing pedestrian connectivity in areas under intensification in Southern Ontario?
    e. What is the state of GI development in areas under intensification in Southern Ontario?
    f. What are the barriers of developing and restoring GI in in areas under intensification in Southern Ontario?
5. How can an integrated design approach to creating GI and pedestrian networks remediate GI and intensification shortcomings?
    a. What are the common barriers for developing GI and pedestrian networks in UGCs?
    b. How are GI and pedestrian networks included in UGC planning?
    c. Is there evidence that the integration of these networks is being considered in municipal planning documents and design guidelines?
6. Where can a connected network of GI elements be realized in UGCs?
    a. Are GI and pedestrian networks compatible?
    b. What are the benefits or drawbacks of this integration for both GI and pedestrian networks?
    c. Where can GI networks be included in pedestrian networks?
7. What are the opportunities for the integration of GI and pedestrian networks in intensified areas?
    a. What challenges are preventing the implementation of municipal plans to realize GI and pedestrian networks?
    b. Are municipalities taking steps to address these challenges? What are key design features that can facilitate the integration of GI and pedestrian connectivity in intensified areas?
8. Can general design guidelines be developed for different municipalities?

This thesis addresses the identified objectives and questions through a structured approach to unravel the core complexities associated with the integration of GI and intensification. To do so, it first looks at literature that exclusively focuses on compatibilities between GI and intensification. This goes beyond the standard literature review that sets the foundation for this work, and instead applies a targeted literature

review with specific detailed systematic search of research on the intersection of GI and density of urban environments. Subsequently, it presents case studies on Urban Growth Centres (UGCs) (i.e., specific areas targeted for intensified development within larger urban regions, aiming to redirect development from downtown areas to other designated centers) in Southern Ontario, Canada. Understanding this region is key, as it has been a pioneer in the practice of intensification, faces massive suburban expansion and population growth, and has a history of comprehensive conservation practices. In addition to the standard research literature, the thesis analyzes many of the specific regional and municipal planning documents associated with the case study areas.

The subsequent research phase involves constructing interviews with a number of expert planning professionals with relevant experience in these fields. The interviews include both structured and open-ended questions, as well as additional conversations with the interviewees. Then, the author systematically visited the case study areas in-person and remotely to study the urban environments, identified the shortcomings in the current interventions and potentials for integrating GI in the case studies such that this integration is aligned with the intensification goals. This has allowed the identification of a host of urban spaces that are suitable for integrating GI to achieve GI connectivity, while complementing pedestrian connectivity. Finally, the thesis articulates a set of urban design tools and guidelines that map to the identified urban design shortcomings, which are showcased in a proof of the concept urban design proposal.

This dissertation utilizes a case study analysis to conduct the research investigation, but its findings are generalizable and can be applied to many UGCs. These findings are directly applicable to the practical planning strategies that are currently being implemented by specific municipalities of Southern Ontario. The strategies have wider applicability as they are derived from multiple UGCs, minimizing the impact of local environmental and institutional variables.

GI planning research emphasizes the benefits of natural systems for humans. This dissertation makes an overarching contribution to GI research in assessing how the incorporation of GI networks in intensified areas enhances intensification planning goals, such as promoting active transportation, which benefits both density planning models and environmental goals. The answers to the questions above will enhance the planning processes of transforming UGCs by improving the conception, design, and evaluation of multi-functional urban infrastructures in intensified areas.

Importantly, this research serves as a methodological and chronological contribution to the body of research that is focused on striking a balance between urban density and the natural environment. In this sense, this dissertation presents a pragmatic approach by gathering evidence that UGCs are planning for

GI networks within the intensified areas, while identifying the roadblocks and gaps in their approaches. Importantly, a distinct planning focus on achieving GI connectivity in public spaces was found. Significant overlaps between GI networks and pedestrian networks were identified. As a result, this research seeks ways by which these two networks can benefit each other, while at the same time be aligned with intensification objectives.

Broadly, this research proposes a series of design guidelines to integrate GI in public spaces of UGCs, such that they provide feasible alternatives to vehicular transportation, while providing ecosystem services to resolve environmental issues in intensified areas.

1.6 Thesis Outline

This dissertation is comprised of five chapters and is organized as follows. Chapter 1, the introduction, presents the research area, the dissertation contribution to the research, the objectives and research questions, and the summary of the dissertation. Chapter 2 includes the literature review, which presents a review of past research on several topics including urban sprawl/intensification, GI, ecosystem services, walkability, and pedestrian infrastructure. It provides a chronological background on the spatial conflict between increasing urban density and promoting natural and semi-natural features by reviewing the previous theoretical efforts to incorporate GI in compact urban environments. This chapter concludes that connectivity is the spatial common ground between GI and intensification planning, which can address the spatial conflicts between GI and intensification. Accordingly, Chapter 2 indicates that the spatial integration of GI and intensification can be achieved using structural connectivity principles from GI planning and pedestrian connectivity principles from intensification planning.

To elaborate on methods that can be applied for the integration of GI connectivity and pedestrian connectivity, Chapter 3 outlines the mixed methods that are applied in the course of the research. It begins by justifying the need for a mixed methodology to tackle the multidisciplinary research of blending GI and intensification. Then it introduces the case study approach by describing the intensification planning context and GI planning in the Greater Toronto Area and introducing the two UGCs of Downtown Mississauga and Markham Centre as case studies. In addition, this chapter describes the content analysis methods, including planning document reviews, in-person interviews, and direct observations. The methodology also includes a systematic search method, which is applied to investigate positive and negative interactions between the GI elements and the built-environment components of compact cities. This includes listing multiple disciplines involved in the analysis, the keywords, the databases, and the elimination processes. This chapter also describes the formation of two tabular urban design tools that describe the structural properties of GI elements in intensified areas and the physical interactions of GI

elements with ‘grey’ infrastructure. Ultimately, the methodology chapter describes how these tools are used to develop the design proposals that demonstrate the integration of GI connectivity and pedestrian connectivity in areas under intensification.

Through applying the above methods, chapter 4 presents the discussion and results of this dissertation. This includes a review of the built-environment barriers to developing GI and pedestrian networks in UGCs, reviewing current strategies for the implementation of these networks, classifying potential UPOSs for the integration of GI and pedestrian networks, and identifying design and planning gaps for the implementation of these networks. These findings are followed by a set of tabular urban design tools for transforming UPOSs in intensified areas by integrating the connectivity of GI and pedestrian networks. Finally, Chapter 5 summarizes the research findings, highlights the research contributions, and provides recommendations for the future research.

Chapter 2
Literature Review

This chapter provides a comprehensive review of two prominent paradigms shaping urban planning and environmental sustainability: Green Infrastructure (GI) and urban intensification. These concepts have gained considerable interest in contemporary urban planning and environmental discourse, particularly due to their potential in combating urban sprawl (i.e. the over-expansion of urban areas into rural land, typically characterized by low-density development, increased reliance on automobiles, and inefficient land use) (Gavrilidis et al., 2017). The focus here is to understand the various ways these two perspectives intersect, their conflicts, and similarities, which have remained largely understudied. Therefore, this literature review aims not just to summarize past studies and their limitations, but also to provide a foundational structure for exploring potential integration of GI and urban intensification. Accordingly, this chapter explores the individual and interconnected implications of GI and urban intensification, paving the way for a comprehensive understanding of their role in fostering sustainable urban environments.

This chapter starts by providing a chronological background of the urban planning attempts to address the urban sprawl. Then, urban intensification is introduced with a focus on the intended outcomes, the strategies used in its implementation, and the necessary conditions for it to be effectively deployed. This is followed by categorizing the intensification strategies in a way that is comparable with GI strategies. The second section delves into GI, beginning with the historical evolution of environmental movements and the formation of the GI concept, its objectives, and policies. The GI strategies are organized in a manner that allows comparison with intensification strategies previously categorized. The chapter concludes by identifying Urban Public and Open Spaces (UPOSs) as likely zones for GI integration within intensified areas, suggesting that enhancing GI connectivity could amplify its benefits and concurrently bolster pedestrian infrastructure.

2.1 Curbing Sprawl

Since the 1980s, various planning models have been studied and implemented as potential solutions for addressing the problem of urban sprawl practices including its numerous environmental, social, and economic shortcomings. Models such as New Urbanism, Smart Growth, and the Compact City have endeavoured to cope with sprawl by providing sustainable urban forms and specific development strategies, evolving over time as the origins of intensification. For example, New Urbanism has tried to deal with the superblocks of suburbs by increasing the density and diversity of housing on the

neighborhood scale in newer developments. Smart Growth (i.e., a planning approach that supports development within existing urban areas, promotes mixed land uses, and pedestrian-friendly streets) and the Compact City models attempt to address suburban dispersion by supporting developments in metropolitan areas and preventing outward expansion beyond city boundaries (jabareen, 2006; Bunce, 2004; Filion & McSpurren, 2007). These models are described in more detail below.

2.1.1 New Urbanism

New Urbanism (i.e., a planning and development approach focused on creating compact, walkable communities with mixed land uses), conceived as an alternative to urban sprawl in the early 1990s is a planning and development approach with a set of guidelines for creating new compact communities. The principles of new urbanism include walkability of streets and blocks, accessibility of public spaces, and proximity of housing and shopping (Iravani & Rao, 2020). These attributes are accomplished through greenfield development projects, where urban form is more contained than suburban development (Xu, 2017). However, new urbanism guidelines do not address the improvement of existing urbanized areas. New urbanism projects generally create new subdivisions on the outskirts of cities instead of working on within existing developed areas, so that they are isolated and have a lack of connection with adjacent areas and services. In terms of the natural environment, new urbanism has not been successful in reducing the ecological footprints of urban sprawl since its projects consume undeveloped lands, do not have significantly higher density than suburban development, and lack public transit infrastructures (Keith et al., 2023).

2.1.2 Smart Growth

The design guidelines of new urbanist practices have been built upon and improved through Smart Growth planning initiatives. Since the1990s, smart growth has emerged as a popular planning approach in the United States for curbing sprawl (Han et al., 2020). Smart growth supports development and expands services within urbanized areas using public policy tools. These include greenbelts and urban growth boundaries as well as design principles, such as infill development, infrastructure cost saving, pedestrian-friendly street design, and mixed-use zoning (Raman & Roy, 2019). However, while smart growth seeks to minimize the adverse effect of urbanization on the environment by preserving larger regional areas for natural space, it lacks guidelines for environmental interventions within cities (Jabareen 2006). While smart growth considers green spaces essential for the quality of life in compact cities, it does not provide design guidelines for developing and managing those (Hansen et al., 2019). Beyond this, smart growth guidelines discuss regional sustainability as a long-term planning concept but does not provide guidelines of the compact urban form.

2.1.3 Compact City

The ‘compact city’ is an interchangeable term for smart growth in Europe. The compact city tries to improve the sustainability of the existing built environment by promoting dense and mixed-use development, public transportation, population density and local services and jobs (Bunce, 2004; Haaland & van den Bosch, 2015). With regard to the natural environment, while smart growth is a response to the loss of agricultural land and environmentally sensitive habitats in the 1960s and 1970s, the compact city promotes conservation strategies by restricting growth to confined urban areas (Leffers & Ballamingie, 2012). The compact city encapsulates other movements that address sprawl, such as Smart growth, New Urbanism, Sustainable Communities and “Neo-traditional Development, which all share the focus on contained (not sprawling), compact (high density), and highly connected urban form (Williams, 2004). Planning for the compact city promotes public transportation, reuse of urban infrastructure, and mix-use and walkable urban areas (Koohsari et al., 2019).

2.2 Intensification

Intensification has gained significant momentum among planners in Canada, United States, Europe, as well as Australia and New Zealand (Biggar and Siemiatycki, 2020; Han et al., 2020, Filion et al., 2020). In urban planning, intensification refers to increasing the density of development in select existing urban areas rather than expanding outwards. Examples include converting a surface parking lot to a series of town homes with underground parking, replacing a few single family detached houses into high-rise apartments, and lifting height limits and zoning restrictions for a specific low density urban block to promote mixed-use buildings (Filion & Saboonian, 2019; Langemeyer et al., 2020; Leffers & Ballamingie, 2013; Melia et al., 2011). Accordingly, intensification can happen at urban scales as small as individual parcels of land. In comparison to the compact city concept, which focuses on compactness within an entire city, intensification more commonly promotes planning guidelines to promote compact development at more strategically targeted neighbourhood and multiple-neighbourhood scales. As part of this strategic planning, the promotion of mixed-use lands, multiple activities, population density, public transit and active transportation are considered. Intensification is interchangeably referred to as ‘recentralization’ (i.e., the process of reversing suburban sprawl by concentrating population and economic activities back into the central urban areas to enhance density, efficiency, and sustainability) and ‘densification’ (i.e., the process of increasing population or building density within existing urban areas through redevelopment or infill, aimed at improving land use efficiency and reducing urban sprawl) (An & Gu, 2018; Brunner & Cozens, 2013; Vecchio & Arku, 2020). In Canada, intensification in urban

areas is backed by provincial and local masterplans and amendments, which enable compact residential and commercial/retail development in pre-defined areas for multiple neighbourhoods.

In terms of sustainability, intensification addresses a wider range of social, environmental, and economic issues than previous planning models that merely focused on urban sprawl. In social terms, intensification seeks to improve affordable housing and to facilitate accessible employment. From an environmental standpoint, intensification seeks to reduce car dependency and improve efficient energy usage. Regarding economic issues, intensification encourages municipalities to better understand and strategize around the fiscal challenges associated with maintaining and expanding urban services and infrastructure, such as transit networks (Cash, 2016; Filion & McSpurren, 2007).

2.2.1 Intensification Goals

To address urban sprawl and achieve urban sustainability, intensification sets various planning goals, including ones that refer to economic, public health, and environmental areas. These goals are addressed by local and regional governments through different policies. Due to the wide range of intensification goals, intensification policies target various fields, such as politics, economies, demographics, technology, and design. Each of these influences implementation strategies. For example, for increasing density in areas under intensification, economic incentives can work in concert with design strategies. Economic incentives encourage infill development and retrofitting projects, while architectural design strategies promote multifunctional buildings and connect them to public transportation (Filion & Saboonian, 2019; Ministry of Municipal Affairs and Housing, 2020a; Tillie et al., 2018).

While this dissertation acknowledges the importance of many different areas of intensification policies and strategies to achieve intensification goals, it primarily focuses on the urban design and planning realm.

2.2.2 Intensification Policies

Key intensification policies deal with increased development density in urban centres, the promotion of mixed use development, and incorporating public transit and active transportation infrastructure (Ministry of Municipal Affairs and Housing, 2020a). These are accomplished by policy changes that impact design, such as lifting the restrictions on building height cap (McCrea & Walters, 2012), setting ambitious projected density targets (Savvides et al., 2019; Tratalos et al., 2007), promoting innovative redevelopment / infill development (C. De Sousa, 2017; Dorning et al., 2015), and incorporating transit priority routes (Lindau et al., 2014).

Importantly, intensification policies promote active modes of transportation, which often work with public transit. Active transportation refers to any human-powered mode of travel, including walking, bicycling, skiing, canoeing, and others. As a transit alternative, it promotes physical activity and requires modest and nonpolluting infrastructure. Intensification policies such as increasing density and promoting mixed-use development can positively contribute to active transportation. For example, a study in Toronto, Canada, illustrates that apartment residents (i.e. mid- to high-rise buildings in areas with increased population density) are more likely to use public transit and walk than residents of low-density houses (Ledsham et al., 2017).

2.2.3 Synergy of Intensification Policies and Strategies

As noted previously, each intensification policy may address multiple intensification goals. For instance, creating a pedestrian and transit-friendly environment can enhance all aspects of urban life, urban efficiency and urban environment because it increases physical activity and reduces energy consumption by and pollutants from cars (Duffhues & Bertolini, 2016). Meanwhile, each intensification strategy addresses multiple intensification policies. Infill development, as an example, increases urban density while reusing existing urban infrastructures (C. De Sousa, 2017).

Intensification strategies may also indirectly serve intensification policies. For instance, retrofitting (i.e., the process of upgrading or renovating existing buildings and infrastructure to make them more energy-efficient, environmentally friendly, or socially functional) surface parking areas increase density while contributing to the development of pedestrian-friendly environments. This suggests that intensification policies should work together, and various intensification strategies should be implemented simultaneously to better achieve intensification goals. This is known as the ‘synergy effect’ of intensification. For example, studies suggest that the combination of pedestrian friendly and mixed-use development attracts more employment than that of each, exclusively. However, there is a lack of explicit design strategies in intensification planning that can contribute to intensification policies (Filion & Saboonian, 2019; Galster et al., 2001; Hansen & Pauleit, 2014; Jabareen, 2006).

2.3 The Categorization of Intensification Strategies

Urban design and planning instruments are essential parts of addressing intensification goals. For the purpose of this dissertation and easy comparison, three primary categories that are applicable to both intensification and GI goals have been identified: urban life, urban efficiency, and the urban environment. This section discusses these categories in the context of intensification. The urban life category focuses on the goal of improving the social aspects of living in areas under intensification (Allen et al., 2018). The

urban efficiency goal discusses the efficiency of intensification infrastructure as well as land protection (Coutts et al., 2019). The urban environment category deals with the ecological goals of intensification (Jim, 2004). For achieving each of these goals, a set of planning and design policies and strategies are defined and described below.

2.3.1 Urban Life Goals

The homogenous urban form of sprawl impedes the quality of urban life. The lack of diversity for land use, housing, and a lack of connectivity within the dispersed built environment contribute to a host of problems, such as longer commuting, job-housing imbalance, marginalized communities, and the reduced appeal of urban environments (Jabareen, 2006; Wheeler, 2000). Intensification has the potential to improve the quality of life in three key areas: resident's health, social dimensions, and the appeal of built environment.

The Health of Residents

A suburban lifestyle is regularly identified as a major contributor to health issues. For example, Iravani & Rao, (2020), demonstrate that spending more hours in cars increases the chance of obesity. Intensification policies and strategies promote active transportation by facilitating any human- powered mode of travel, such as walking and bicycling (Iravani & Rao, 2020; Ledsham et al., 2017). In mixed used lands and transit-oriented development active transportation is promoted through design strategies for creating infrastructures for pedestrians and cyclists, developing multifunctional buildings, increase the diversity of housing, and improve the design features of public spaces. For example, a study in Toronto, Canada, argues that bike trips are more likely to be taken from apartment buildings than from houses (Ledsham et al., 2017). As another example, Saelens & Handy, (2015) explore how in mixed-use lands, the presence of sport facilities and outdoor amenities proximate to work and living space increases the chance of using them.

It is generally expected that in reducing car dependency will reduce automobile-related air and noise pollution, and in turn improve human health. However, studies criticize intensification for environmental consequences such as increasing air pollution, higher crime rates, overpopulation, and noise pollution (C. De Sousa & Ridsdale, 2021; King et al., 2012; Kuo, F. E., & Sullivan et al., 2001; Williams, 2004). These consequences are generally associated with two issues. First, alternative modes of transportation are often not attractive enough, and personal cars, even in higher density areas, remain the preferred mode of transportation. Second, dense urban environments lose basic environmental functions, such as shade and fresh air, and thus reduce the appeal of being outdoors (Ramyar et al., 2019; Shi et al., 2021).

To address the above issues, this dissertation will recommend that developing GI in areas under intensification not only improves the environmental functions of cities but also encourages active transportation. For example, the transformation of Gellerup-Toveshøj in Aarhus, Denmark included the demolition of a handful of apartment blocks to restore a central park into a new city park for promoting active transportation (Pauleit et al., 2019) while creating natural environments, that promote restorative ecosystems.

The Appeal of the Built Environment

Intensification improves the quality of urban life by enhancing the appeal of the built environment (Blečić et al., 2016). Some of the built environmental features that attract human activities and development are measurable, such as marketability, cleanliness, and safety. Others, however, are unmeasurable, such as enhancement of urban design, and improvement of local identity (e.g., improvement of views, and streetscape enhancement) (Koschinsky et al., 2017). Intensification strategies that can increase the attractiveness of built environments include increasing the diversity of building types, reducing the occupancy of public lands by cars, creating walking/cycling corridors, and developing public green spaces. Diversifying building types in mixed-use lands is associated with an increase in marketability by attracting a more diverse range of industries and employers (Jabareen, 2006; Long & Rice, 2019; Rey & Lufkin, 2016). Reduced occupancy of public lands by cars is associated with cleanliness and safety (Saidla, 2018). Creating walking and cycling corridors increase the presence of people in streets and helps promote safety (Koschinsky et al., 2017).

This dissertation will demonstrate that GI can contribute significantly toward enhancing the appeal of built environment. A study in Rotterdam, Netherlands, showed that the popularity of living in inner city neighborhoods correlated with attractiveness of their GI, with regard to the number of Boulevards, Quays, Squares, playgrounds, parks, and green roofs/facades. It also demonstrates that a mix of high-quality GI elements in a comprehensive network of interlinked spaces can address different user needs, promote physical activity, and provide human-nature connection (Burgess, 2013; Tillie et al., 2018).

Social Dimensions

Intensification can also enhance the social aspects of urban life and provide a diverse range of urban spaces that meet human needs. This is accomplished through policies and strategies that diversify urban services (e.g., educational, retail, working, gathering, and recreational spaces), facilitate access to services, increase housing options, and create human-scaled urban spaces (Duffhues & Bertolini, 2016; Ledsham et al., 2017; Williams, 2004; Yan & Zhou, 2016). For example, it has been found that increasing

housing types increases cultural and social diversity through creating a variety of household features, such as age, income, and size (Artmann et al., 2017; Jabareen, 2006).

This dissertation demonstrates that importantly, developing GI elements in intensified areas also improves social elements, such as social cohesion, recreation, and income difference. For example, green roofs on condominium towers provide communal spaces that create a unique sense of place, provide restorative access to nature, and trigger social interactions (Langemeyer et al., 2020).

2.3.2 Urban Efficiency Goals

The dispersed development of suburbanization results in the consumption of natural and agricultural lands outside city boundaries (Hennig et al., 2015). The suburban lifestyle is also associated with the inefficient use of natural resources, long commutes with personal automobiles, and high-energy consumption of large houses. In sprawling urban areas, linear infrastructure such as water, sewer, and electricity grids must extend over larger distances to serve dispersed populations, increasing installation and maintenance costs. Additionally, the suburban infrastructure serving lower population densities is not used as intensively as in compact urban settings, leading to underutilization of the invested resources (Shao et al., 2021). Intensification increases the efficiency of cities in urban infrastructure costs per capita by concentrating development where urban infrastructures already exist (Vecchio & Arku, 2020).

Land Efficiency

For promoting land efficiency, the main intensification policy relates to increasing development density in order to curb land use and development dispersion. This can be accomplished with design strategies such as downtown revitalization and brownfield development (Rey & Lufkin, 2016). Leveraging opportunities for multifunctional GI is one of the main strategies in downtown revitalization processes. For instance, stormwater management ponds in Tampa, FL, which are necessarily abundant in heavily urbanized areas for flood control, have been considered as suitable locations to develop parks as part of revitalization initiatives for granting public access to green spaces (Wright Wendel et al., 2012).

Infrastructure

For intensification, infrastructure efficiency refers to developing efficient energy and water infrastructures and functional public transit. Design strategies, such as upgrading existing infrastructures (e.g., improving power-grid efficiency, and implementing new piping systems for sustainable water management), and promoting transit-oriented urban centres can contribute positively to energy efficiency (Barresi, 2018; Lobaccaro & Frontini, 2014). GI measures contribute to energy efficiency by alleviating the Urban Heat Island effect in intensified areas. This aspect of GI is used in the plans of Bologna and Farnza, Italy, for

instance (Conticelli et al., 2017). In terms of water efficiency, there are numerous examples of GI strategies in use, such as Xeriscapes (i.e., A landscaping approach that emphasizes using drought-resistant and water-efficient plants to reduce water consumption) for reducing water consumption for irrigation, and rain harvesting for reducing domestic water use (D. Kim & Song, 2019; Meyer et al., 2014).

2.3.3 Urban Environment Goals

Urban sprawl degrades the environment on the regional scale in a multitude of ways. Foremost among these are the loss of habitat and reduction biodiversity by consuming natural and agricultural lands outside city boundaries, and increased environmental pollution due to non-vegetated and impervious surface area, and reliance on cars to reach dispersed services. For example, while studies show that impervious surface areas in intensified urban regions are higher than in suburban areas, the overall impervious surface area is significantly smaller on a regional scale when sprawl is limited (Searle & Filion, 2011).

Intensification strategies try to conserve natural lands through confining urban boundaries and limiting the consumption of natural resources outside intensified areas, while reducing environmental pollution from automobile use (Barresi, 2018). However, numerous studies suggest that limiting sprawl does not compensate for the adverse effects of intensification on the environment. For instance, Ward et al. (2015) argue that although it is often asserted that urban intensification reduces CO_2 emission regionally, it does not change transportation behaviour on the local scale. Hence, the peak in traffic over the rush hour, and the longer hours of traffic during daytime increases CO_2 emission in areas under intensification as compared to that of the suburbs. As another example, Owen (2004) explores how the cumulative CO_2 emission in urban environments is higher than that of suburbs due to the emission from buidings and the lack of CO_2 flux from vegetation (Owen, 2004).

Research further suggests that intensification poses significant challenges to urban green spaces through infill development and consolidation due to its lack of specific propositions for GI provision and conservation. Unfortunately, even though intensification proponents argue that private green spaces can be replaced by public green spaces, public green spaces in compact cities rarely offset the loss of private green space GI benefits (Haaland & van den Bosch, 2015).

2.4 Green Infrastructure (GI)

GI is increasingly recognized as the main strategic contributor to environmental planning. However, opportunities to create, enhance, and diversify GI elements in intensified areas are limited due to the competition over land (Boo & Kwon, 2018; Dorning et al., 2015). To better understand the incorporation

of GI in intensification planning, the following section investigates GI goals, policies and strategies and explores a potential common ground between GI and intensification. This is accomplished by reviewing the evolution of GI policy and strategy in planning articles, and then classifying these in the same breakdown as intensification goals: urban life, urban efficiency, and urban environment.

The precise term "green infrastructure" was first used by Cornelissen (1986), to discuss the recreational benefits of green and open spaces. Later, the definition was elaborated upon by Benedict and McMahon (2002) to identify GI as a significant urban infrastructure. However, the notion of GI is rooted in much earlier planning and design movements. This section will first review the evolution of GI and subsequently provide a study of GI policies and strategies in the literature.

2.4.1 Historical Origins of the GI Concept

GI can be traced to the green movements of the 19th and 20th centuries, such as City Beautiful, Parkway movements, and the Garden City, which tried to develop greenbelts, boulevards, and united park systems as defining feature of urbanized areas (Madureira et al., 2011; Rising, 2019; Tan et al., 2013). While a primary focus of these concepts was providing public access to green spaces for recreational benefit, they also had some intention to protect the environment through planning for connected green and open spaces in natural, rural, and urban landscapes. For example, the Ecopolis movement in Soviet Union between 1917 and 1991 focused on developing ecologically designed towns, which were committed to protect natural landscapes and to create comfortable conditions for citizens while enhancing the creativity of science (Ignatieva et al., 2011). However, at that time, open spaces and natural areas were perceived to be plentiful, leading to a focus on economic development and job creation rather than prioritizing their preservation. Hence, conceptualizing green spaces as necessary assets for human wellbeing was difficult to make as a central focus (Griffith, 2010).

2.4.2 The Emergence of Environmental Concerns

Valuing the natural environmental aspects of green spaces began in earnest with the environmental movements of 1960s and 70s in the USA and other parts of the world. The Clean Air Act of 1963, the Clean Water act of 1972, the Endangered Species Act of 1973 in the USA, and other comparable global examples are frequently cited as early instances of environmentally protective laws (Mell & Clement, 2019). Importantly, the greenway movement in the 1980s and 90s in the United States and Canada (referred to as "green corridors movement" in Europe) directly influenced the ecological design of natural features in cities by introducing connected networks of green spaces. In addition to recreational and historical benefits, these corridors provide various environmental benefits, such as maintenance/

enhancement of biodiversity, migration pathways for wildlife, prevention from flood risk, and improvement of water quality (Ignatieva et al., 2011).

By the late 1990s and early 2000s environmental awareness about the importance of natural protection led to the creation of supportive laws and assessment tools for green space planning. This development made Environmental Impact Assessments a mainstream component of development processes, to assess the environmental, socio-ecological, and economic impacts of development activities. Hence, the assessment and mitigation of adverse landscape changes became more convenient due to the prominence of environmental policies (Ignatieva et al., 2011; Mell & Clement, 2019). Since then, ecological disciplines such as landscape ecology, landscape planning, and landscape architecture have had greater influence in the development of greenways (linear corridors with different widths, linked to a network), greenbelts, and greenspaces to underpin cities by promoting conservation, acknowledgement, and enhancement of the natural processes through research and design (Fabos, 1995; Ignatieva et al., 2011; Turner, 1995; Walmsley, 1995).

2.4.3 Evolution of the GI Concept

GI term was coined by Cornelissen (1986), to discuss open space policies for attracting tourism in the Netherlands (Cornelissen, 1986). However, the conceptual origins of GI are often attributed to the urban park networks and wilderness resorts created by renowned landscape architects such as Frederick Law Olmsted and Robert Moses. These pioneers viewed GI as "breathing rooms" and new destinations for urban residents, though their designs did not fully address the broader environmental dimensions of GI (Teaford et al., 1987).

In urban settings, GI has long been contrasted with “grey infrastructure” - the conventional, engineered structures and systems built primarily for managing human services, such as roads, sewage systems, and water treatment facilities, typically made of concrete, steel, and other manufactured materials. GI as a natural component of urban infrastructure was described in the late 1990s, when the governor of Maryland and the governor-appointed Florida Greenway Commission mentioned GI as “statewide greenway systems”. This highlighted the significance of GI planning in civil societies as being of equal consideration to grey infrastructure (Firehock & Walker, 2015).

An elaboration of the GI concept was first developed by Benedict and McMahon (2002), when GI was defined in relation to being an interconnected network of natural and semi-natural features, or both areas that are protected in their natural state, such as conservation areas and riparian zones, and areas or features that are deliberately constructed, such as storm ponds and bioswales (Benedict et al., 2006; Griffith, 2010; Hoctor et al., 2008; Mell & Clement, 2019). This specific acknowledgment of GI

highlighted its benefits for conserving natural ecosystems, enhancing human health and well-being and distinguished green spaces from being exclusively for recreational use. GI elements, sometimes referred to as GI typologies, can be classified according to the (often multiple) functions they serve. Now, as GI planning has evolved in the past two decades, GI policies have expanded from focusing on conservation and biodiversity to including infrastructure improvement and ecosystem services provision through the implementation of these various elements or typologies (Bartesaghi-Koc et al., 2019).

2.4.4 The Evolution of GI Policies and Strategies

As a reaction to urban sprawl, urban GI was envisioned as ecological networks which would compensate for the loss of natural areas in urban areas. Accordingly, GI policies started to manifest themselves as urban planning decisions that were aimed at revitalizing, protecting, and conserving natural features and their numerous functions of ecological systems within, between, and around urban areas (Ignatieva et al., 2011; Tzoulas et al., 2007). These policies address GI planning goals from different dimensions of urbanization, such as economic, ecological, social, public health, infrastructure, and the environmental dimensions. A thorough breakdown of GI economic policies (e.g., incentivising GI elements) and GI ecological policies (e.g., providing additional habitat for urban wildlife) are outside the scope of this dissertation, but they do have a direct impact on planning and design strategies available for the built environment that are investigated here. Hence, the following section discusses GI policies and strategies that lead to design solutions for achieving a broad range of GI goals from conservation/ biodiversity to urban infrastructure and ecosystem services. GI policies and strategies are described in a chronological order as follows.

Conservation and Biodiversity Policies and Strategies

Biodiversity in urban environments refers to the variety of organisms and multiplicity of habitats in and around compact human settlements. Appropriate environmental conditions support water, energy, food, medicine and other nutrients, which are essential for human health and wellbeing. It also creates economic opportunities and social activity (World Wildlife Fund Canada, 2022). Conservation is referred to environmental protection efforts, such as natural resource management and use to achieve social, ecological and economic benefits. Natural conservation policies include protecting individual parcels of land, valuing open space networks, and addressing the extinction and replacement of native species (Cirella, 2020).

In the early 2000s, when harms of rapid urbanization and urban sprawl posed to natural lands and biodiversity began to be more thoroughly understood, the ability of GI to support conservation and biodiversity efforts came into sharper focus. For example, McKinney (2002) argued that the high

extinction rate of native species, created by urban sprawl, should be mitigated by protecting existing habitats from development and revegetating disturbed areas with native species. Marzluff (2001) suggested that for preserving bird habitats, nests, predators, and food availability, ecologists and urban planners should collaborate to ensure a healthy biodiversity in cities is maintained (Marzluff, 2001; McKinney, 2002).

GI conservation policies including conservation easements, land use regulations, green space protection, biodiversity corridors and connectivity planning, stormwater management, stewardship programs, and GI incentivizing, can be supported and reinforced by design strategies. For example, GI measures, such as xeriscaping (i.e. a landscaping method with plants that require minimal water, aiming to create green spaces that are sustainable and water-efficient), can create the balance between the population of urban adaptive and non-adaptive species. They can also support the endangered species that are eradicated from suburban landscapes due to the dominance of monotonous landscapes, such as grass lawns with a limited variety of aesthetical trees (Benedict et al., 2006; Blair, 2001; Cadieux et al., 2013; Marzluff, 2001; McKinney, 2002)

Infrastructure-oriented Policies and Strategies

While conservation-oriented policies deal with the natural elements of GI, another trend of GI research focuses on the ability of purposefully engineered GI to address urban infrastructure issues, in particular, water issues. Since the beginning of the 21st century, problems caused by the pressure of rapid urbanization on grey infrastructure (e.g., flooding, combined sewer overflows, and blockage of natural water infiltration) have been increasingly recognized (Keeley et al., 2013; Nickel et al., 2014). Although grey infrastructure solutions, such as pump stations and treatment plants to address urban runoff issues increase the capacity of sewer systems, they do not address the root cause of these problems, such as the replacement of pervious soils that provide point-source infiltration with hard and impenetrable urban surfaces that create mass runoff (A. Karvonen, 2011).

Urban runoff is a non-point source problem because it is produced over the entire area of urbanization, which cannot be addressed by conventional water infrastructure. Multiple studies discuss the capability of GI in assisting conventional water infrastructure through nature-based solutions (Meerow et al., 2021; Rai et al., 2019; Tsegaye et al., 2019). Nature-based solutions refer to the deliberate use of specific natural processes, including water retention, infiltration, filtration, and evapotranspiration to deal with urban runoff (Ronchi et al., 2020). Accordingly, GI typologies, such as bioswales and vegetated strips, can be distributed throughout urbanized areas and reduce the speed, volume, and pollution level of urban runoff at individual sites. (M. Byrne, 2008; Foster et al., 2011; Krauze & Wagner, 2019). This resulted in

mainstreaming GI planning and design for addressing other non-point source issues, such as urban heat island and air pollution (Dushkova & Haase, 2020; Lafortezza & Sanesi, 2019).

Design strategies that can combine GI typologies, such as downspout disconnects, green roofs, rain gardens, and bioswales with grey infrastructure often serve as the primary tools for any sustainable stormwater management programs that intend to retain and infiltrate the same amount of precipitation on site as the predevelopment condition. Globally, some of the most well-known water programs include Low Impact Development (LID) in the USA, Sustainable Urban Drainage Systems (SUDS) in the UK, Water Sensitive Urban Design (WSUD) in Australia, Biotope Area Factor (BAF) in Berlin, Germany, and Green Area Ratio (GAR) in Seattle, USA (Keeley, 2011). Cheng et al. (2001) describes how LID measures, such as bioswales, rain gardens, and rain barrels transform development sites into functioning landscapes by increasing pervious surfaces and slowing runoff. These strategies can improve retention and detention storage, encourage the meandering nature of water flow routes, and increase pollution prevention measures, such as oil filtering. LID is still considered to be synonymous with GI on many official plans in different cities, although GI as a design approach has much wider application (Cheng et al., 2001; Sansalone et al., 2013).

Beyond water management, GI can increase the efficiency of electricity generation, distribution grid, and heating/cooling infrastructure. One study by Semeraro et al. (2020) describes that placing photovoltaic panels on green roofs can increase their efficiency by a range from 1.3% to 8.3% (Semeraro et al., 2020). It has been further identified in a range of research studies that trees can reduce cooling energy consumption by providing evapotranspiration and shading, while acting to decrease the demand for heating energy by reducing heat transfer, air exchange, and wind speed (Wise, Braden, Ghalayini, Grant, Kloss, Macmullan, et al., 2010).

Water and energy benefits are not the only services provided by GI. Over time, a tremendous number of benefits have been linked with having natural systems in urban settings. Collectively, these benefits have been formalized under the umbrella of the term “ecosystem services” (Chaudhary et al., 2015).

Policies and Strategies for Providing Ecosystem Services

Since the early 2000s, studies have highlighted the heavy reliance of human health and wellbeing on the health of ecosystems in urban areas. “Ecosystems” can be understood to refer to the interaction between biotic and abiotic components, which leads to the exchange of nutrients and energy. Ecosystem services are the outcome of ecosystems in the form of goods (e.g., food and raw materials) and services (e.g., cleaning air and water, and maintaining the water cycle), which are essential for human health and well-

being (De Groot et al., 2012; Food and Agricultural Organization of the United Nations, 2022; Gómez-Baggethun & Barton, 2013; Naumann et al., 2011).

GI is a major contributor to the provision of ecosystem services. The biotic systems of natural and semi-natural features of GI allow natural processes, such as water infiltration. Abiotic parts of urban areas, such as buildings and roads either block and/or conduct the movement of nutrients, which, then, modify the number of services that ecosystems produce. For example, the biotic components of bioswales include surface vegetation, and the abiotic parts are reduced slopes, gravel and pebbles (with specific grain sizes), and perforated drainpipes, which are attached to storm sewers. This combination allows an amount of filtration, retention and gradual release of urban runoff (Everett et al., 2015).

The concept of ecosystem services can be historically linked to the publication of Silent Spring, which warned the potential burdens of environmental degradation for humans between the 1860s and 1960s (Brand & Karvonen, 2007; Yan & Zhou, 2016). This was followed by defining ecosystem services, in 1981, as the services relating to natural systems (Chaudhary et al., 2015). In 2001, the Millennium Ecosystem Assessment (MEA), an innovative study on a global scale, divided ecosystem services into the four categories: supportive, provisioning, regulating, and cultural ecosystem services. Supporting ecosystem services assist the production of other ecosystem services. Provisioning ecosystem services deliver products and goods from ecosystems. Regulating services manage ecosystem functions, such as air movement and heat transfer. Cultural ecosystem services are nonmaterial benefits of the ecosystems and add cultural and social benefits. This classification is used in the research of ecosystem services (Millennium Ecosystem Assessment 2005).

Since urban ecosystem services can provide a wide range of benefits from health, economic, and social benefits to spiritual benefits, ecosystem services are studied in a range of different landscape and planning research areas. These include: urban sprawl, human livelihoods, green space development, health, economic value, and tourism using a variety of methods, including land cover assessment, GIS, economic valuation, surveys, and urban planning. At the same time, GI has been identified as a primary source of ecosystem services in urban areas (Chaudhary et al., 2015; Droste et al., 2018; Tzoulas et al., 2007). Accordingly, the initial application of GI as exclusively a water regulation tool has expanded to other ecosystem services, such as carbon sequestration and air quality improvement. Exploring the economic cost of implementation and maintenance, taking into account all ecosystem services provided, as well as the various socio-cultural values of preserving open spaces, home gardens, xeriscapes, and green streetscapes has been of significant interest in the research community in recent years (Gómez-Baggethun & Barton, 2013; Wise, Braden, Ghalayini, Grant, Kloss, MacMullan, et al., 2010). From a social and

health perspective, it has been demonstrated that access to parks and green streets can promote physical activity; exposure to bird sounds can reduce stress levels; and encounters with wild plant species can facilitate environmental education. (Kowarik et al., 2021; Säumel et al., 2016; Weber et al., 2014). Coutts and Hahn (2015) argue that the presence of GI increases the amount of walking.

At the same time, technical knowledge for evaluating GI for a wide range of ecosystem services, such as reducing GHG emission and air/water pollution (among other ecosystem services) has expanded. For example, Pataki et al., (2011) shed light on regulating biogeochemical cycles other than water, such as carbon, nutrients, and pollutants cycles, that are impacted by urban plants, soil, and landscapes (Pataki et al., 2011; Spatari et al., 2011). Moreover, recent research has highlighted the significance of Traditional Ecological Knowledge (TEK) for evaluating GI. This often-underrepresented resource offers invaluable insights into sustainable land-use practices of indigenous peoples, which are deeply tied to the principles of GI. For instance, Indigenous communities have long emphasized interconnectedness between ecosystems, similar to the connectivity goals of GI networks. Practices such as wetland preservation and controlled burning to manage landscapes align with contemporary interventions to enhance biodiversity and ecosystem health. These approaches can assist GI designers to integrate native species, restore ecological systems, and foster cultural recognition. For example, replanting wetlands with culturally significant plants such as sweetgrass or cattails can improve ecosystem services while honoring Indigenous traditions (Berkes, 2012; Kimmerer, 2013; Turner, 2005).

Despite the abundance of literature about the evolution of GI in the urban context, there is still a lack of design strategies and guidelines for generating urban ecosystem services in GI planning. The following section reviews the state of current GI strategies in articles and describes them in the context of the same three categories of urban life, urban efficiency, and the urban environment used to analyze intensification goals. This method of categorization is intended to illuminate the common ground between GI and intensifications a basis for developing design strategy.

2.5 Categorization of GI Goals and Strategies

As described in the previous sections, throughout the evolution of GI it has been demonstrated that there is clear interest in leveraging the health, social and economic benefits of GI beyond its environmental benefits. Numerous GI articles discuss the role of GI in improving urban infrastructures and providing various ecosystem services (Erker & Townsend, 2019; Thompson et al., 2019). In the following sections, these interests will be described in relation to the contribution of GI to urban life (the health of residents, social aspects of urbanity and the appeal of built environment), to urban efficiency (the efficiency of both

urban lands and urban infrastructures), and to urban environment (improving the natural environment of cities and regulating the environment within cities for residents).

2.5.1 Urban Life Goals

GI can improve various aspects of urban life, ranging from enhancing physical and mental health to bolstering social dynamics and environmental education. Importantly, GI can enhance the appeal of the built environment for humans, which increases various urban life qualities, such as aesthetics, safety, and placemaking. The benefits of GI for urban life can be described as the health of residents, the appeal of the built environment, and the social dimensions associated with urban dwelling (Giles-Corti et al., 2011; Hislop et al., 2019; Rey & Lufkin, 2016).

The Health of Residents

GI strategies can improve both the health of environment within urban settings, as well as the physical and mental health of urban dwellers. Environmental health is linked to human health and well-being, as seen in GI policies focused on air and water pollution control and biodiversity. (Young and McPherson, 2013). For example, the City of Seattle, USA, considers the health of its salmon species as an indicator of a healthy environment for its residents. Accordingly, a number of strategies are implemented to reduce the pollution and volume of urban runoff discharged to the creeks of Seattle, which serve as an important habitat for salmon species. This includes a scoring system (Green Area Ratio) for the implementation of GI in new developments (Jack Ahern et al., 2014) and a program for retrofitting (i.e., the process of upgrading or renovating existing buildings and infrastructure to make them more energy-efficient, environmentally friendly, or socially functional) streets with GI elements (Green Street Program). The GI elements that have been implemented in these programs include small wetland ponds, cascade pools, rain gardens, and vegetated swales. Monitoring these strategies shows that reducing an 11% of impervious surfaces by GI results in 98% reduction of stormwater flow and the Combined Sewer Overflows (CSOs) (i.e., The release of untreated or partially treated sewage and stormwater from a combined sewer system during heavy rainfall events) risk, both of which are threats to the salmon population (Nolon, 2016).

Building on this, the impact of GI on walking and other types of active transportation is a major focus in the research literature. For example, a study in Portland, Oregon, USA, discovers that the “Gray to Green” program of greening streets, which was initially for resolving stormwater issues, significantly promotes walking. Attractive GI elements, such as ferns and shrubs increase the appeal of the built environment better than rudimentary grasses and encourage pedestrian activity, such that attractive GI elements such as street catchment basins promote walking better than developing street connectivity and on-street parking (Adkins et al., 2012).

With respect to the impact on mental health, studies suggest that GI can contribute to reduced anxiety and overall improved community satisfaction. For instance, Cameron et al. (2012) highlight that one of the key benefits of urban gardens is their role in the prevention and recovery from illness. Having gardens and natural space in close proximity has been shown to facilitate exercise and increase engagement with nature. Moreover, the presence of flowers and water bodies are particularly effective in reducing stress. These elements tend to be more impactful than other factors such as the presence of animals, scents, and sounds, which, although beneficial, may not be as strongly associated with stress reduction (Cameron et al., 2012; Wolch et al., 2014) . Other examples include the positive relation between incorporating green walls and roofs on commercial buildings and office towers, which are correlated with higher workplace productivity and fewer sick days (Revell & Anda, 2014).

The Appeal of the Built Environment

Studies demonstrate that GI can significantly enhance the appeal of the built environment. Adding open and green spaces to buildings, improves a number of built environment qualities, including cleanliness, aesthetics, and safety level. Sustainability indicators of GI such as pollution control and biodiversity provision can positively correlate with areas that attract new development and revitalization projects because they are perceived to be more desirable (Arnberger & Eder, 2012; Gavrilidis et al., 2017; Snäll et al., 2016). For instance, a study in the inner city of Rotterdam, Netherlands, highlighted how adding 5000 trees and green space covering 150 soccer fields attracted more inhabitants and visitors to the neighbourhood (Tillie et al., 2018). Another study discusses how buildings with green roofs and green walls tend to provide more opportunity for attractive photos and videos, which improve the perceived appeal of the neighbourhood for land managers (Bolliger & Silbernagel, 2020).

Social Enhancement

GI can also support important social dimensions of urban life by promoting social activity, social interaction, social cohesion and both environmental education and awareness. The development of GI measures in communal and recreational spaces support social activity and interaction (Pauleit et al., 2019). The Rose Fitzgerald Kennedy Park in Boston, MA is a particularly good example of how GI can contribute to social cohesion. As a long, linear greenway and civic space that replaced the former expressway, it connects a diverse range of neighbourhoods in the downtown area and creates opportunities for civic exchange through a variety of elements, including parks deliberately designed to celebrate different cultural groups, passive and active recreational spaces, and temporary and permanent green art installations intended to engage public dialogue (Mahmoud, 2022; Rembeza, 2017). GI can further help to educate people about the environment and create opportunities for them to become

environmental stewards. For example, studies argue that formalizing long exposure to wild grown species in Berlin, Germany through developing them in entrances and paths can educate people about their ecological values and increase acceptance of their inclusion (Andersson et al., 2014; Kowarik, 2018; KOWARIK, 2021; Kowarik et al., 2021; Young & McPherson, 2013).

2.5.2 Urban Efficiency Goals

Urban Infrastructure Efficiency

GI can reduce pressure on grey infrastructures while decreasing the demand for water and energy infrastructures overall. GI can both supplement and serve as an alternative to the overly stressed grey infrastructures in dense urban areas. For instance in order to reduce the pressure on grey infrastructures, GI reduces and eliminates the need for constructing new large pipes and channels that transport urban runoff out of cities (Schäffler & Swilling, 2013). Incorporating bioswales beside streets and along storm-sewers and vacant lands significantly reduces the rate and volume of urban runoff discharge into sewers and decreases incidents, such as CSOs, flooding and erosion. Modeling simulations in Milwaukee, USA show that neighbourhoods with GI could experience about 30-40% reduction in stormwater volumes and CSOs (Foster et al., 2011; Zhang et al., 2019).

GI interventions are strategic approaches that can reduce demand on domestic tap water and energy consumption (Caird & Hallett, 2019; Calderón-Contreras & Quiroz-Rosas, 2017; Schäffler & Swilling, 2013; Ward et al., 2015). GI measures increase ground water recharge, which helps decrease drought events and the need for irrigation. For example, new developments in downtown Berlin must include permeable areas for water infiltration and recharge to Berlin's groundwater in addition to semi-natural solutions, such as artificial wells and aquifers, which inject the treated urban water into the groundwater (Hansen et al., 2019; Mathey et al., 2015; Quintas-Soriano et al., 2019). GI strategies can further reduce energy demands through vegetated surfaces, including green roofs and green walls that provide shade and regulate the urban temperature (Foster et al., 2011; Lehmann, 2014; Spatari et al., 2011).

Land Efficiency

Regarding land efficiency, GI policies can reduce the consumption of natural land by incorporating parks and allotment gardens in urban areas. For example, developing accessible GI in city centres has been shown to reduce demand for secondary homes outside of the city boundaries (Módenes & López-Colás, 2007). It has further been identified that producing food in urban farms and on balconies and rooftop gardens can reduce the demand for transforming natural land to farmland (Cao & Natuhara, 2020; Koyata et al., 2021).

2.5.3 Urban Environment Goals

The environmental goals of GI focus on two primary areas: improving the environment, and regulating the urban environment for urban dwellers. Improving the environment addresses conservation, biodiversity provision, and ecosystem services provision, which either cannot be delivered by grey infrastructure (e.g., carbon sequestration) or requires considerable investment (e.g., flood risk reduction) (Puppim de Oliveira et al., 2022). Regulating the urban environment refers to reducing the harshness of the urban environment for urban dwellers such as temperature regulation and pollution reduction. Both goals are critical for human wellbeing and survival (Mekala et al., 2015).

Regulating the Urban Environment for Residents

By providing regulating ecosystem services, GI can contribute to improving the urban environment for humans. This is facilitated by two approaches to environmental policymaking and GI design. The first approach addresses environmental issues through the lens of climate change mitigation and adaptation (Sussams et al., 2015). GI interventions have the capacity to mitigate, or actively slow, climate change, and at the same time enable urban residents to adapt to the reality of a changing climate. For example, GI can assist in GHG emission reduction and energy consumption in urban areas (i.e. mitigation policies), and at the same time help to alleviate climate extremes and protect against extreme storm events, such as severe flooding (i.e. adaptation policies). Tree canopy and vegetative covers contribute to this by sequestering carbon and mitigating CO2/O2 imbalances. Furthermore, GI urban designs that focus on the rehabilitation of infiltration and evapotranspiration processes can address extreme flooding incidents stemming from climate extremes (Kousky et al., 2013; Wise, Braden, Ghalayini, Grant, Kloss, MacMullan, et al., 2010).

The approach focuses on regulating the flow of environmental variables, such as pollution, temperature, and sunlight, to maximize urban comfort. This is accomplished by adding vegetated surfaces, vertical green walls, and other types of GI to the built environment to filter and reduce air and noise pollution, decrease the energy loss of buildings, and create thermal comfort. Increasing forest space, trees, and green roofs throughout cities can reduce air pollution through balancing CO2/O2, and restoring the processes of air filtration and pollution absorption (Säumel et al., 2016). Furthermore, it has been shown that shrubs can decrease traffic noise for nearby sidewalks (Food and Agricultural Organization of the United Nations, 2022; Pamučar et al., 2016; Pérez et al., 2016; Pugh et al., 2012). Interestingly, Emmanuel and Loconsole (2015) shows that by adding more street trees, mini-parks, roof gardens, grass areas, and green walls, there is a 20% increase in the green coverage, which reduces the surface temperature by 2°C for an

average 35m by 30m block size. Clearly GI intervention can make a significant difference in the environmental comfort and safety of urban areas.

Conclusion

In the preceding sections, GI and intensification goals were separately examined in relation to three primary categories of urban life, urban efficiency, and urban environment. This approach helps demonstrate how from a broad perspective, both GI and intensification try to improve the same aspects of urbanity, while defining these aspects through different lenses which result in different policies and strategies. An exhaustive review of policy was beyond the scope of this study, but the implementation strategies are of significant interest for their applicability to potential comprehensive design guidelines. In the following section, the identified strategies are compared to draw key findings from this literature review.

2.6 Comparing GI and Intensification Strategies

In the previous section, the shared goals of intensification and GI, as well as some of their individual policies and strategies were identified. As discussed, although the goals of intensification and GI are similar, their policies and strategies may differ. This section compares the implementation strategies to provide a concise summary of the findings from this literature survey. It should be noted that although policies are deliberately not compared in this analysis, GI and intensification policies did not interfere with each other. The intention here is to identify synergies and conflicts between intensification and GI strategies exclusively.

Table 2-1 contains a summary of the strategies presented in sections 2.3 and 2.5 for implementing intensification and GI, respectively. The shared goals are listed on the left columns. For each goal, the intensification policies, intensification strategies, GI policies, and GI strategies are listed in a row. In addition, the discussions in sections 2.3 were used to determine if each intensification strategy aligns with overall implementation of GI. Accordingly, each strategy is labelled as “oppose”, “complement”, or the “same”. An opposing intensification strategy acts as an obstacle for implementing GI. For example, “increasing development density” reduces the available space for green open spaces. A complementary strategy supports the implementation of GI. For example, “facilitating access to urban services” provides opportunities to develop urban parks as an urban service. Lastly, a few intensification strategies are similar to GI strategies or directly promote GI development. These strategies are labeled as the same. For example, “developing GI in downtown revitalization processes” directly promotes the incorporation of GI in downtown areas. These labels are included in parentheses in the table. Similarly, the interaction

between GI strategies and intensification implementation were determined based on the discussions in section 2.5.

Table 2-1 Comparison between Intensification and GI strategies.

		Intensification Policies	Intensification Strategies	GI Policies	GI Strategies
Urban Life	Public Health	Reducing car dependency Promoting physical activity Reducing environmental pollution	Increasing development density (e.g. in-fill development, redevelopment, retrofit projects) (Oppose)	Improving the health of environment Improving physical and mental health of the residents	Conservation and Biodiversity (Complement)
			Promoting non-motorized transportation (Complement)		Ecosystem services provision (Complement)
	Appeal of the Built Environment	Attracting human activities Attracting development	Increasing development density (Oppose)	Increasing built environment qualities Attracting new developments	Adding open spaces (oppose)
			increasing the diversity of building types (Complement)		
			creating walking/cycling corridors (Complement)		Adding vertical and elevated green spaces (complement)
			developing green spaces (Same)		
	Social Dimensions	Social interaction Social equity Social diversity	Diversifying urban services (complement)	Social activity Social cohesion Recreation Environmental education	Developing GI measures in communal and recreation spaces (complement)
			Facilitating access to urban services (complement)		
			Increasing housing options (complement)		Developing GI measures to connect a diverse range of neighborhoods (complement)
			Creating human scaled environment (complement)		Developing GI measures in entrances and pathways (complement)
Urban Efficiency	Land Efficiency	Settling a greater number of people in smaller areas	Increasing development density (oppose)	Reducing the consumption of natural land for housing Reducing the demand for farmland	developing accessible GI in city centres (oppose)
			Developing GI in downtown revitalization processes (same)		producing food in urban farms and other GI measures (complement)
	Infrastructure Efficiency	Placing cities, where urban infrastructures already exist	Improving infrastructure capacity (e.g., improving power-grid efficiency, and implementing new piping systems for sustainable water management) (complement)	Reducing pressure on grey infrastructures Decreasing the demand for water/energy	Implementing GI elements that enhance the capacity of grey infrastructure (e.g. bioswales reduce the need for new large pipes and channels) (complement)
					Implementing GI elements that act as alternative source for water (e.g. rain barrels produce water) (complement)
Urban Environment	The environment	Reducing the consumption of natural lands	Confining urban boundaries (oppose)	Conserving natural habitats Providing Biodiversity Improving the functionality of ecosystems	Establishing urban green corridors (same)
					Promoting urban reforestation (complement)
	Environmental variables for urban residents	Developing public open spaces	Transforming suburban parks to urban parks (complement)	Adapting to the impacts of climate change Mitigating the causes of climate change Regulating environmental variables (e.g. flow of water, air, and heat)	Providing Ecosystem services (complement)

Table 2-1 demonstrates that the majority of GI and intensification strategies are complementary to each other. This observation demonstrates the common ground between GI and intensification (Heins, 2015). Moreover, the similarity of some strategies shows that intensification might naturally lead to GI development. However, intensification does not provide design guidelines for GI implementation.

The comparison between GI and intensification strategies shows that the conflict between them is associated with the limited development space in urban cores. Intensification strategies demand space to increase development density, while GI strategies intend to create more open-spaces. In other words, the conflict between GI and intensification hinges on the development of the built environment. However, this conflict seems resolvable, as intensification masterplans often recommend that a portion of the dense urban environment be dedicated to GI integration. Primary obstacles are a lack of consensus around the appropriate spaces to integrate GI, as well as the lack of success that current strategies have in achieving a comparable GI functionality in dense urban areas as compared to that in suburban areas. Regarding space constraints, identifying potential urban spaces that are suitable for integrating GI elements is required.

GI development is a significant strategy that can contribute to the entire range of intensification policies, from the improvement of urban life to the efficiency of urban infrastructure. For example, Haaland and Van den Bosch (2015), suggest that density should be understood through the lens of environmental qualities for residents rather than just as a quantitative measure since green space change is the most noteworthy issue of intensification (Haaland & van den Bosch, 2015). However, studies argue that there is a lack of environmental dimensions in the core of intensification policies. Although intensification highlights the environmental intention of smart growth and emphasizes reducing the damage of suburbanization on the environment, GI has not been discussed in intensification planning (Haaland & van den Bosch, 2015; Maes & Jacobs, 2017).

The current strategies to achieve comparable functionality from GI elements in limited spaces of dense urban cores and landscapes with more green space availability (i.e. natural landscapes, farmlands, and suburban development) have not been successful. The reviewed literature showed that urban parks alone in intensified areas are not providing the environmental and social benefits that larger green open spaces provide outside the intensified areas. Therefore, there is a substantive value in addressing how to improve the functionality of GI elements in areas under intensification. Understanding the mechanisms that improve the functionality of GI in intensified areas requires conducting a multidisciplinary and targeted research that covers topics such as ecosystem services and connectivity. The methodology for this research is described in Chapter 3 and the findings are presented in Chapter 4.

2.7 UPOSs as Common Space for Developing GI and Intensification

Reviewing the literature reveals that from the built environment perspective, GI and intensification strategies both require the development of urban public open spaces (UPOSs) to implement changes that achieve their respective goals. Intensification strategies aim to develop and redevelop UPOSs to promote density, mixed-use lands, and transit-oriented developments, while GI utilizes the space available in UPOSs to maximize greenspace, mitigate negative impact of urbanization on the environment, and produce ecosystem services. Indeed, UPOSs are the "common space" of GI and intensification planning, and thus can be a primary ground for synergies and conflicts between the two. These spaces are covered in more detail in the Chapter 4 and the terminology will be used frequently throughout this dissertation.

GI and intensification both seek to address their common goals in UPOSs. To improve urban life, intensification targets UPOSs to promote active transportation, increase the appealing of the built environment, and encourage social interactions. At the same time, GI aims to increase the number of green elements in UPOSs, such as streets, communal spaces, and recreational spaces to promote cultural ecosystem services (Paulit Pauleit et al., 2019). To achieve urban efficiency, intensification planning conceptualizes UPOSs as central hubs of mixed-use development and public transit. Meanwhile, the GI approach seeks to create visible natural infrastructures (e.g., tree canopies and bioswales) in UPOSs to provide supporting and regulating ecosystem services, such as tree planting for air purification and bioswales for stormwater management (Módenes & López-Colás, 2007). For the urban environment, intensification focuses on reducing the environmental issues of cities by promoting UPOSs that can facilitate active transportation and public transit usage. At the same time, primary policies of GI address protection, biodiversity enhancement and ecosystem services provision through conserving, restoring, and developing GI networks in UPOSs. Bringing together, the dual perspectives of GI and intensification in UPOSs show a great potential for blending GI and intensification in these spaces.

2.8 Conclusion and Lessons Learned

This literature review chapter has delved into GI and intensification within urban spaces. Both these elements, when considered individually, contribute vastly to the sustainable and efficient development of cities. However, the main point of this study is to understand where they overlap, and the problems and opportunities that come with it.

Many intensification and GI strategies display complementary characteristics, signifying their synergies in urban planning. The common ground between GI and intensification, as established through this investigation, revolves around sustainability attributes such as multifunctionality and connectivity. This

shows that there is potential to establish robust multifunctional and connective networks for both GI and intensification, if it is guided by informed urban planning and design. However, the competition for space in urban cores is evident. Intensification seeks to maximize the utility of available space, increasing the population and activity density. Simultaneously, GI requires open spaces to deliver its environmental and social benefits. Both intensification and GI view UPOSs as critical avenues to realize their respective goals. If the objectives of GI and intensification can be harmonized within these UPOSs, developing compact yet green cities seems feasible.

The literature review identified the need for holistic design strategies that cater to both GI and intensification objectives. While a few pioneering studies put forward the idea of harmonization of green spaces within compact city frameworks, a comprehensive design strategy, especially one that emphasizes connectivity and multifunctionality, is not developed yet. The present research trend, which recognizes the co-existence potential of GI and intensification, offers a path forward. The emphasis on shared sustainable attributes underscores that with innovative urban design and forward-thinking urban planning, the conflict between GI and intensification can be mediated. In the coming chapters, we will argue that promise lies in integrating GI structural connectivity with pedestrian connectivity to transform urban spaces into sustainable, green, and efficiently intensified areas.

To conclude, this chapter establishes the foundational premise that while challenges persist in integrating GI within intensified urban domains, the path forward is clear. Through multifunctional designs, enhanced connectivity, and an emphasis on UPOSs, urban design can achieve a harmonious blend of GI and intensification. The subsequent chapters will delve deeper into design strategies and methodologies to realize this harmonized vision.

Chapter 3
Methodology

This chapter presents the methodology employed for this dissertation, forming the foundation upon which the study's outcomes are based. A detailed description of the methodology allows for a clear understanding of the steps in conducting the research, the reasons underpinning the decision making, and the mechanisms behind deriving the results and conclusions. To investigate the complex problem of integrating GI and urban intensification, an exploratory sequential mixed method was utilized, comprised of both qualitative and quantitative research methods. A multi-dimensional methodological approach was necessitated by the complex and multi-faceted nature of a research problem that is related to various fields and disciplines.

The methodology chapter starts by justifying the need for a mixed methodology by explaining the worldviews, research questions, and the need for a case study approach. This is followed by data collection strategies and detailing data analysis procedures/techniques. Broadly, the data used in this research are collected from previously published works (i.e. through targeted literature review and systematic search) and the planning context of the case studies (i.e. plan reviews, interviews, and direct observations). The coding process and its corresponding steps are described, in addition to the identification of themes. Moreover, this chapter discusses the application of design proposals for both case studies, and the incorporation of "research through designing" (RTD) methodology. The chapter concludes with a summary, outlining the complete methodological path that was taken for this study.

3.1 Designing a Mixed Methods Approach

This chapter outlines the overall exploratory sequential mixed methods research design of this dissertation. This chapter also provides justification for, and descriptions of this study’s methodological design. As the starting point, it explains the complexities associated with integrating GI and intensification, and provides a set of research questions that frame the direction of this research. The chapter then explains the reasoning for selecting a case study approach in the context of Southern Ontario, Canada, introduces the selected case studies, and compares their planning context. It describes the data sources used for this research, which include a targeted literature review, review of the planning documents of the case studies, interviews, and direct observation, and explains the methodology for analyzing the collected data. The chapter concludes by discussing how the lessons learned from this research were applied to develop urban design proposals for integrating GI and intensification within the case study area.

3.1.1 Worldviews and Research Questions

This research is grounded in two streams of study. First, it draws upon prior studies in sustainable stormwater management, urban design, and architectural design. These include case studies of sustainable stormwater management in different cities across the globe. Some of the previous projects that contributed to this study included case studies of sustainable stormwater management systems in Melbourne, Australia; Berlin, Germany; Seattle, USA; and Rotterdam, Netherlands (Keeley, 2011; Mekala et al., 2015; Tillie et al., 2018).

Before initiating this research, I had conducted some limited case study exploration about sustainable stormwater management programs in seven different cities across Europe, North America, and Australia. I reviewed their planning documents and conducted interviews to identify the gaps between their policies and programs. From this work, I developed a framework of design guidelines for practical and feasible sustainable stormwater management planning (Saboonian, 2014). Second, this research is informed by recent investigations that were conducted of metropolitan planning and intensification in North America regarding recentralization of the inner cities, as opposed to the sub-urban expansion (Filion & Saboonian, 2019).

Bringing together these different streams of study has shed light on numerous conflicts within the field of urbanization. One recurrent issue is the challenge of dealing with the spatial conflicts between natural environments and concentrated human settlements. The mixed methodology of this dissertation has been devised specifically to address the spatial conflicts arising between the two concepts of GI and intensification.

Studies suggest that GI and intensification can be compatible. The planning documents of Southern Ontario municipalities do demonstrate intentions for integrating GI into the intensification processes of UGCs. This is consistent with the current studies that suggest GI and intensification can be aligned (Heins, 2015). However, such intentions have not been fully realized yet.

In this dissertation, a case study approach is taken to identify the real-world obstacles that prevent this integration. Subsequently, the case studies allow an exploration of tools for addressing these obstacles as the findings of this dissertation. Therefore, this dissertation does not fall under postpositive, constructive, and transformative worldviews because it neither verifies and generates a theory, nor intends to induce political reforms. Rather, it follows a pragmatic worldview by focusing on current intensification practice and its shortcomings with regard to incorporating GI networks (Creswell & Creswell, 2018).

This chapter outlines a methodology that enables urban designers to incorporate GI networks in UGCs to address environmental issues related to intensification, while promoting active transportation. The

methodology makes use of the connectivity created by GI elements for both GI and pedestrian networks. This approach helps to address various urban environmental issues by providing various ecosystem services, including promoting physical activity.

3.1.2 Research Questions and Mixed Methods

The research questions in Chapter 1 provided a broad framework for the literature review in Chapter 2. Through the literature review conducted in this study, parts of the questions initially posed in the introduction have been answered. For example, the evolution of GI and intensification planning in articles was covered in sections 2.2 and 2.4, respectively. Building on these insights, a more focused set of questions is developed, tailored to address the specific aspects of this integration. Accordingly, the following refined research questions are used to develop the methodology with a targeted and manageable scope for this thesis:

1. What is the possible methodology to integrate GI in UGCs?
2. How can UGCs be on-track toward integrating GI and intensification?
3. Are there enough spaces in intensified areas to integrate GI elements and revitalize GI connectivity?
4. What are the spaces that can place the integration of GI and intensification? What are the shortcomings and obstacles to integrating GI in intensification planning?
5. How can these shortcomings be addressed?
6. What is the feasibility for developing universal design guidelines for GI and intensification integration?
7. What details should be included for these design guidelines?

To address these multifaceted questions, a mixed methods research design was deemed most appropriate to understand the complex topics involved. Mixed methods can examine the complex factors of this study, such as the locations of GI integration, the attractiveness of urban development for humans, and the perception of safety for pedestrians (which influence environmental health and human well-being). Mixed methods can also help assess the effectiveness of strategies and programs of GI and intensification, as well as inform practice decisions about them (Brown, 2017).

A downside to selecting mixed methods is the need to collect multiple sources of data and analyze them, which can be quite time consuming. No limitations were applied to the data sources, which included official plans, interviews, direct observations, and spatial data. These sources required a mix of qualitative and quantitative approaches to analyze and draw conclusions from (Creswell & Creswell, 2018).

This study employed an exploratory sequential mixed methods approach for integrating both qualitative and quantitative data gathering and analysis. The expected outcomes from mixed method case studies often enhance a greater and more detailed understanding of the similarities and differences between multiple cases (Kazmierczak & Carter, 2010). In this dissertation, this notion refers to the barriers and approaches of two case studies toward integrating GI and pedestrian networks. The mixed methods approach can also be used to develop suitable mechanisms for a set of cases, which in this dissertation was the identification of generalizable urban design instruments for achieving GI and pedestrian connectivity at the same time.

Figure 3-1 shows the three phases of this mixed methods design, where each phase informed the subsequent phase (Creswell & Plano Clark, 2011). Phase 1 includes initial qualitative data collection and analysis. The data sources complement each other, and the analyses were conducted at the same time. For example, interview questions were informed by a preliminary review of municipal documents, and then the interviewees might provide or direct to other potential interviewees, new supplementary plans, guidelines, or briefs that were either overlooked or not publicly available at the time of the initial document review. In Phase 2, a systematic search of the relevant published work regarding GI and pedestrian networks in intensified areas was performed. The outcomes of this phase were used to synthesize two design tools: a GI typology, and an ecosystem services look-up table. The details of the systematic search method are presented in 3.3. These tools were verified in the Phase 3 through developing urban design proposals.

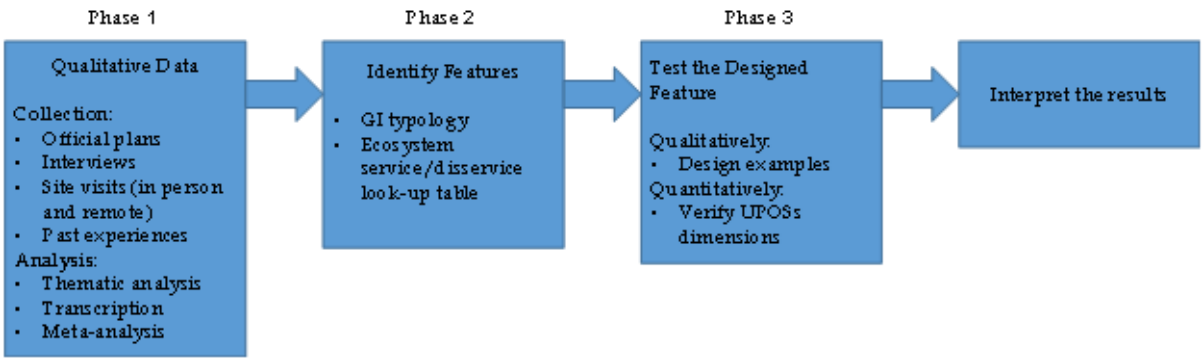


Figure 3-1 Overview of the research design

The exploratory sequential mixed methods design was chosen for a specific set of reasons (Boman et al., 2017). First, a large part of the data collected came from open-ended questions asked during interviews and subjective observations made during site visits. This approach was referred to exploratory instead of explanatory data collection method since it resulted in gathering information in an exploratory way, rather than simply addressing predetermined questions. Importantly, the qualitative data obtained through the

site visits provided a better understanding of the context and allowed the researchers to identify current urban design and planning issues that might not have been apparent from interviews and planning documents alone. As Creswell and Creswell (2018) note, qualitative research often involves multiple data sources, such as interviews, observations, and documents to provide a nuanced and contextualized view of the research topic (Creswell & Creswell, 2018).

Second, the qualitative and quantitative components of this methodology were not separated, as they work to inform each other. For example, qualitative site visits for information gathering (e.g., comparing the mix of uses in two clusters of development) were followed by quantitative measurements (e.g., measuring the distance between crosswalks for later numerical comparisons).

Third, multiple qualitative methodological components, including content analysis of official plans, interviews and site visits were analyzed alongside each other to develop the design tools for identified UPOSs. The design tools were applied to generate alternative scenarios for designing the UPOSs, and the dimensions measured using Google Earth to verify their suitability with the available space and context.

The use of spatial data and GIS methods was contemplated as a method for analyzing and visualizing the designs in Phase 3. However, this approach was rejected for several reasons. First, GIS is a static (i.e. updated infrequently), two-dimensional representation of cities. However, the development in UGCs is dynamic, and often changing due to new development, infill development and redevelopment projects. Hence, spatial data cannot always keep pace with rapid urban fabric changes (Gahegan, 2018). Second, GIS relies on pre-determined indicators such as population density, green spaces in downtown areas, and street trees, which are useful for assessing existing systems (e.g. parks in downtown areas, or green spaces). However, this dissertation addresses opportunities and barriers for creation of GI and pedestrian networks, many of which are qualitative (e.g. lack of local knowledge) (Rusche et al., 2019). Finally, as Artmann et al. (2019) note, a comprehensive assessment of an integrated network of GI and intensification requires the collection and analysis of data for a large quantity of different indicators (their suggested number is close to 75). Therefore, conducting a GIS study would require the availability of many data sources combined with the efforts of a large group of researchers, both of which were beyond the capacity of this dissertation.

This research design included four qualitative and one quantitative method. The second stage of this research, in-person interviews, received ethics clearance through the University of Waterloo Research Ethics Committee and individual agreement from each participating interviewee.

3.2 Case Studies

A case study research strategy has been employed to examine the outcomes from the literature reviews. This broadly includes examining the current state of GI and Intensification in case study areas, current interventions, obstacles, and real-world implications of integrating GI and pedestrian networks. As the literature review suggests, there is a lack of design guidelines and space provision for both GI and pedestrian networks in the context of intensification. The research focused on metropolitan areas in Southern Ontario, because of the following reasons. Firstly, this region is one of the few examples of recentralization planning occurring in North America. The region is undergoing rapid development and population growth, with many recent developments in planning policy and legislation introduced to address conflicting interests in housing and natural space preservation. Accordingly, the UGCs in Southern Ontario were selected for the high visibility and abundant documentation available regarding spatial conflicts in development. Second, conducting case study research in this region was not subject to significant financial constraints as the researchers resided in close proximity to the case study UGCs, enabling frequent in-person site visits and interviews. Finally, there has been significant knowledge developed by this research group regarding the history and planning of this region, which reduced the required time for gathering the initial set of planning documents and reports.

3.2.1 Overview

Integrating GI in urban areas using a case study approach is a focus of this dissertation. Case studies have proven to be a popular research design method for GI and pedestrian. For example, Rossini (2019) used multiple auditing instruments (e.g. remote observation, video analysis, pedestrian counting, informal interviews, and questionnaires) to gather data about the existing condition of public spaces, and how they changed after implementing temporary and modular seating facilities.

A case study approach in general is a useful method for collecting and analysing data from complex systems (Creswell & Creswell, 2018). Both GI and pedestrian networks are complex systems because they depend on multifaceted, geography-dependent variables, such as urban density, landscape type, and climatic region. In addition, multiple stockholders play roles in their planning, design, and implementation, such as residents, municipalities, and conservation authorities.

Creswell & Creswell (2018) and Yin (2010) suggest a case study method for an in-depth study of a "process" which is bounded or constrained by an "activity". A case study approach can identify factors that influence a process in either a positive or a negative way (e.g. gentrification and urban interventions). In this dissertation, the process is the 'integration of GI' and the activity is 'intensification in UGCs'. In other words, this dissertation sought to determine how the process of integrating GI into urban areas could

occur within the constraints of the intensification activities currently happening in those areas. As such, the anticipated outcome of this case study analysis was to develop design instruments that would facilitate the integration of GI specifically for UGCs under intensification planning.

The case study analysis of GI is a practical method for understanding how GI and ecosystem services are integrated in land use policies and planning strategies (Dimarino et al., 2019). For example, the authors have already performed a case study analysis of intensification to identify the challenges of intensification planning in UGCs in relation to their initial planning model, secondary environmental issues and accommodating green spaces (Saboonian & Filion, 2019). Cumulatively, the case study method was useful for assessing potential design options simultaneously with policy and planning strategy.

The outcomes of qualitative research are usually applicable to a specific site or context. However, the qualitative results from case studies with more than one case can be reliably generalized (Creswell & Creswell, 2018). This requires choosing cases that have similar context related to research questions while having significant differences. Accordingly, the following criteria were used to select the case studies for this research:

- The centres should be located in closely comparable, highly urbanized contexts. Therefore, UGCs belonging to small and mid-sized cities were excluded.
- The UGCs should be in the process of transformation by similar intensification targets. Therefore, UGCs that are either already highly developed (such as downtown Toronto), or have little development, were eliminated.
- The UGCs should have significant green spaces.
- The municipal government staff (urban planners, policy makers, etc.) should be available for interviews.
- The UGCs should be different in terms of the challenges facing local governments in implementing intensification strategies. This allows for drawing broader conclusions compared with studying UGCs with similar challenges.

3.2.2 Intensification in Southern Ontario

The studied geographic region of Southern Ontario is referred to as the Greater Golden Horseshoe (GGH). The focus area of this study is the Greater Toronto Area (GTA), which includes the City of Toronto and its neighbouring regional municipalities of Peel, York, Durham, and Halton. The GGH is approximately 33,500 km^2 in size, radiating more than 150 kilometres out from the Toronto downtown city centre. The GTA is 7,124 km^2 in size and hosts a population of about 6.7 million. The region is

unique in North America due to the regional focus on developing centres of high residential and commercial / retail density in suburban areas. In the mid-1970s, planning strategies for the GGH began to focus on reducing the concentration of employment and the pressure on the transportation in Downtown Toronto. This resulted in the increased development in municipal "nodes" such as North York and Scarborough that were close to downtown Toronto. These municipalities, together with five neighbouring ones, were amalgamated in 1998 to form the current City of Toronto. Outside the City of Toronto, other municipalities such as Mississauga adapted a similar model of nodal planning – identifying multiple dispersed centres to focus intensification planning - to develop their downtowns.

Nodal planning was further enriched by a proposal from IBI Group in 1990 that suggested the urban centres be connected through a network of rapid and frequent transit (Filion & McSpurren, 2007). Although this was discontinued in the mid-1990s due to lack of interest by the provincial government, some suburban municipalities, such as Markham proceed to build their own centres. Concurrently, concerns regarding environmental conservation and sustainable development were rapidly taking hold in planning policies.

Currently, the Planning Act requires the different levels of government in Ontario shall be consistent with the Provincial Policy Statement (PPS) regarding minimum standards for the planning matters (Ministry of Municipal Affairs and Housing, 2020b). Accordingly, four provincial planning policies shape the development in Southern Ontario. This includes *A Place to Grow: Growth Plan for the Greater Golden Horseshoe (Growth Plan) for* recentralization on a metropolitan scale, *the Greenbelt Plan, Oak Ridges Moraine Conservation Plan,* and *the Niagara Escarpment Plan* for natural protection from further fragmentation and development (Ministry of Municipal Affairs and Housing, 2019, 2020a).

The Growth Plan identified 25 urban centres in 2006, and required municipalities achieve a certain density threshold for combined residential and office development and promote additional land use planning policies based on the PPS (Cash, 2016; Saboonian and Filion, 2019). The comparison between the 2006 Growth Plan and the most recent version in 2020 shows that sustainability goals, such as climate change adaptation and resiliency are added to the primary focus of intensification and transit (Ministry of Municipal Affairs and Housing, 2020a; Ontario Ministry of Infrastructure, 2006).

GI and associated terms such as "low impact development" were absent in the initial plan and regarding environmental planning, only positive directions for the protection of the Greenbelt areas and the identified natural systems were set. "GI" as a term is mentioned only nine times in the updated version of Growth Plan for stormwater management to reduce flooding risk against climate extremes. The use of "*intensification*" term has slightly dropped from 57 times in the 2006 plan to 47 times while the use of

"*complete community*" term has significantly increased from only nine times in 2006 to 25 times in 2020.

Complete communities refer to mixed-use neighbourhoods with access to daily necessities, including employment, the choice of transportation, divers housing options and public service facilities, including recreation, health, educational and cultural services. The public service facilities contain the public urban GI elements such as urban parks and street trees.

The Growth Plan has clear directions for the protection of greenbelt and natural systems, but regarding GI development, it only encourages municipalities to develop parks or open-spaces without any instructions. It has an ambiguous and partial approach to GI. First, GI is only considered for the singular purpose of stormwater management and its potential for delivering various ecosystem services are not captured. Second, the potential of GI development within complete community areas, such as stormwater management areas, public service facilities and transportation corridors are not discussed. Third, while GI connectivity is an important factor to improve natural systems, policies that can improve GI connectivity in public and open spaces has remained almost intact.

To study the integration of GI and intensification, initially, three UGCs were identified: Downtown Mississauga and Markham Centre outside of Toronto but within the GTA, as well as Etobicoke Centre inside the City of Toronto. They are all characterized by large lot sizes, high-speed arterial roads, and vast surface parking lots (resulting in a lack of route options for pedestrians). Etobicoke Centre was added after conducting the first round of interviews, in order to increase the diversification of studied UGCs, with respect to their environmental challenges, interaction of GI network with other urban infrastructure, and scale of development. However, subsequently the data collected for Etobicoke Centre was redacted from this study because participant interviews could not be scheduled, and the analysis of the planning documents resulted in similar outcomes as the other UGCs.

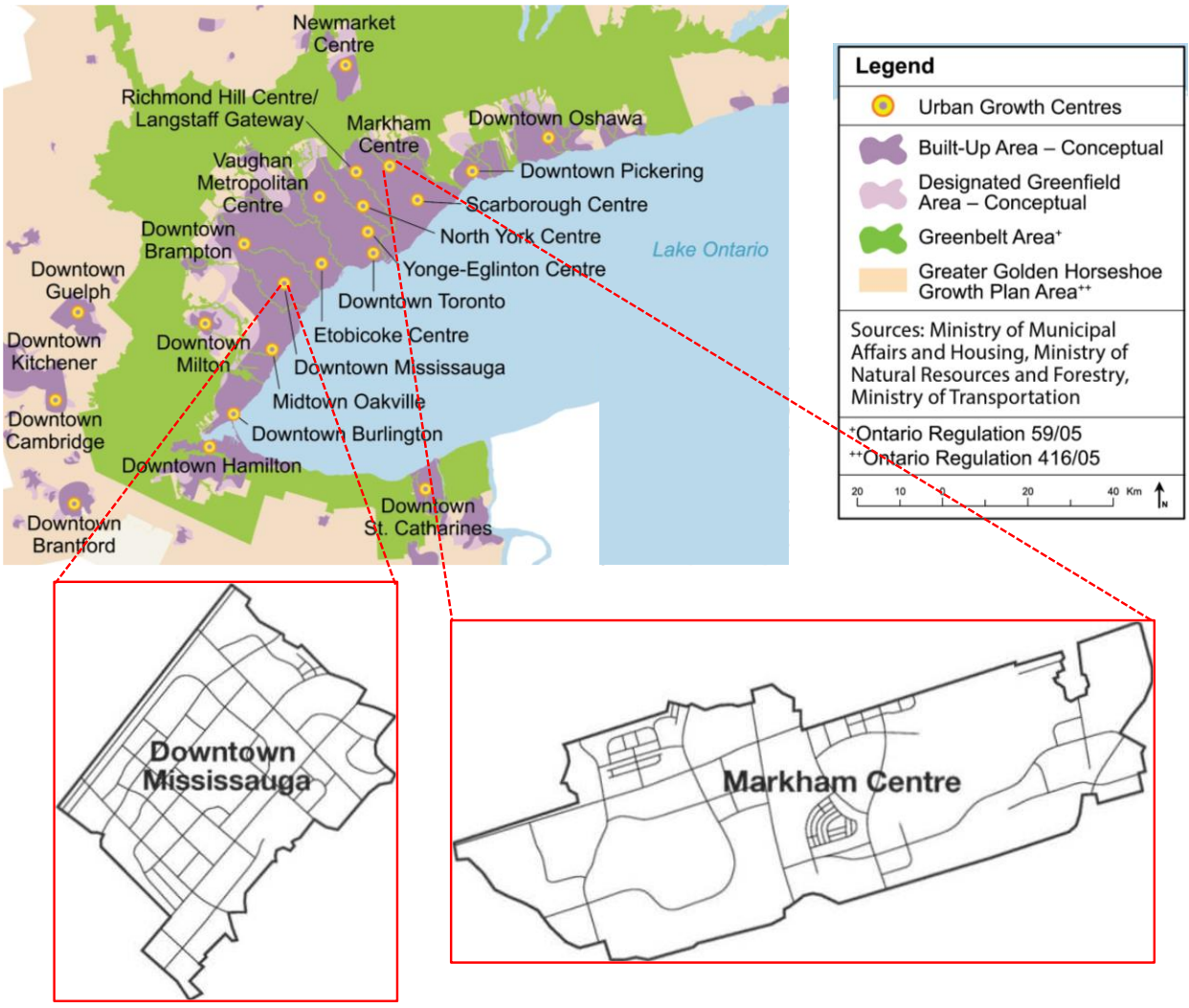


Figure 3-2 Boundaries of Downtown Mississauga and Markham Centre, and their locations with respect to other UGCs near Toronto.

Figure 3-2 illustrates the most recent boundaries of Downtown Mississauga and Markham Centre. They are the largest UGCs in the GGH after Downtown Toronto. As both centres are within the GTA and outside of the City of Toronto, they are comparable in terms of employment and commutation. Both are centres of their respective regional municipalities and both include their municipal and civic buildings. Under the Growth Plan, both UGCs are slated to achieve a density of 200 jobs and residents per hectare density by 2031 (City of Mississauga, 2010; City of Toronto, 2017; Filion, 2007). However, the development in Downtown Mississauga started before the popularization of new urbanism. As a result, these two centres are facing different challenges in achieving their intensification goals. In the following, the two case studies are briefly introduced by providing a description about their location, chronology of their development, and their urban planning context.

3.2.3 Downtown Mississauga

The area designated today as Downtown Mississauga is situated on the traditional territory of the Mississaugas of the Credit First Nation and has been a gathering place for various Indigenous nations including the Anishinaabeg, the Haudenosaunee Confederacy, the Huron-Wendat, and Wyandot Nations. Historically, this area was part of a vast network of hunting grounds, fishing sites, and trading routes used for thousands of years before European contact. The Mississaugas of the Credit continue to steward their heritage through active engagement with urban developments in their territory (Surtees, 1985; Smith, 2002; City of Mississauga, 2024). Located in the Peel Region, the Growth Plan describes the Downtown Mississauga as the area on both sides of Highway 403 and surrounding of the Square One Shopping Centre, in addition to the area alongside Hurontario between Highway 403 and Queensway East, which has an approximate area of 1500 ha (Ontario, 2013). Due to its massive size, the City of Mississauga has a masterplan for guiding growth in an area of 598 ha between Highway 403, Burnhamthorpe Rd, Confederation Parkway, and of Hurontario Street, as shown in Figure 3-3. This area is referred to as Downtown Mississauga.

The Downtown Mississauga is a distinctive UGC due to the presence of the Square One Shopping Centre as its focal point and the proximity of the Pearson International Airport. As the largest shopping centre in Ontario and the second largest shopping centre in Canada, the Square One mall is surrounded by enormous surface parking areas as well as several significant built environment features, such as the Civic Centre, Mississauga Celebration Square, Sheridan College, and many high-rise residential/office buildings. Downtown Mississauga is a significant transportation hub in GTA due to the function of the Square One Bus Terminal for regional and local transportation systems, as well as truck transportation from the airport as an important local industry.

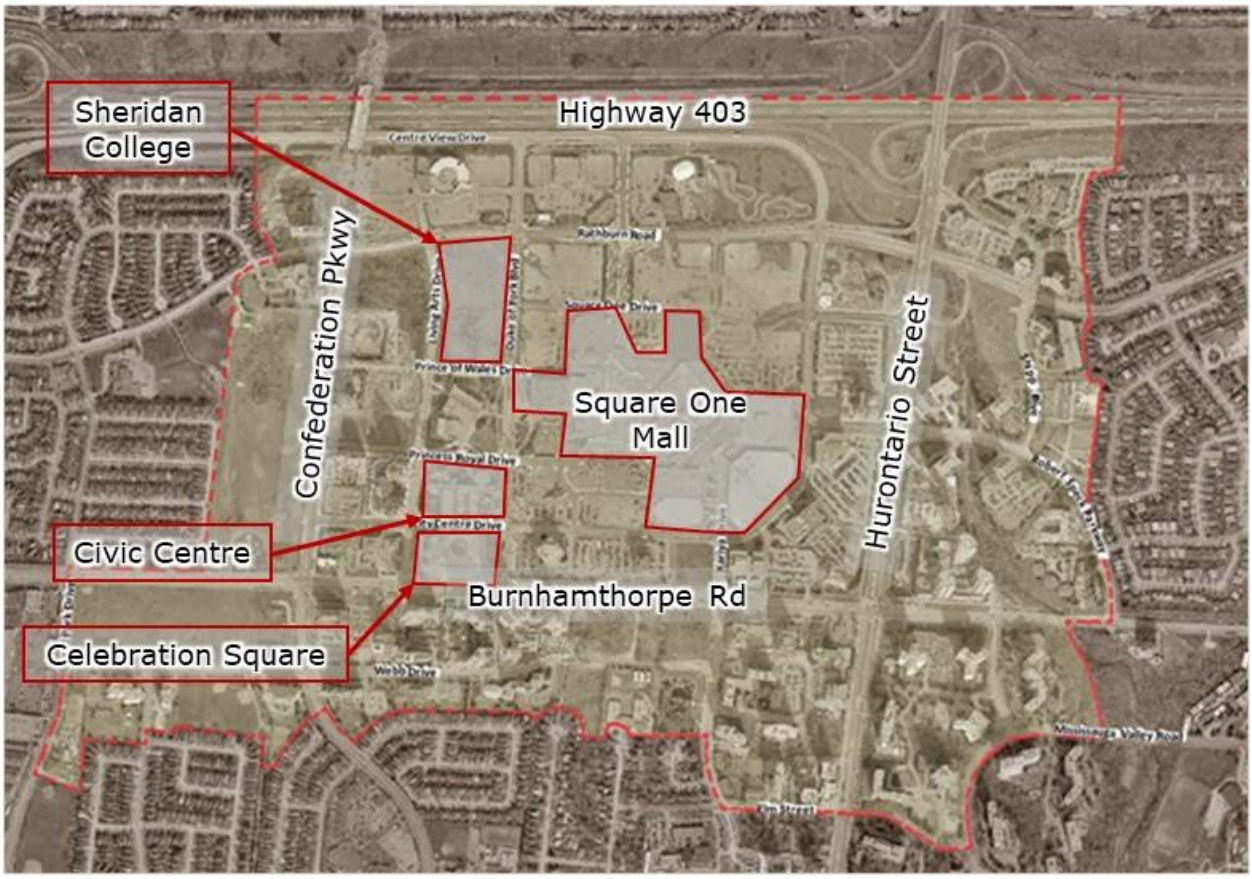
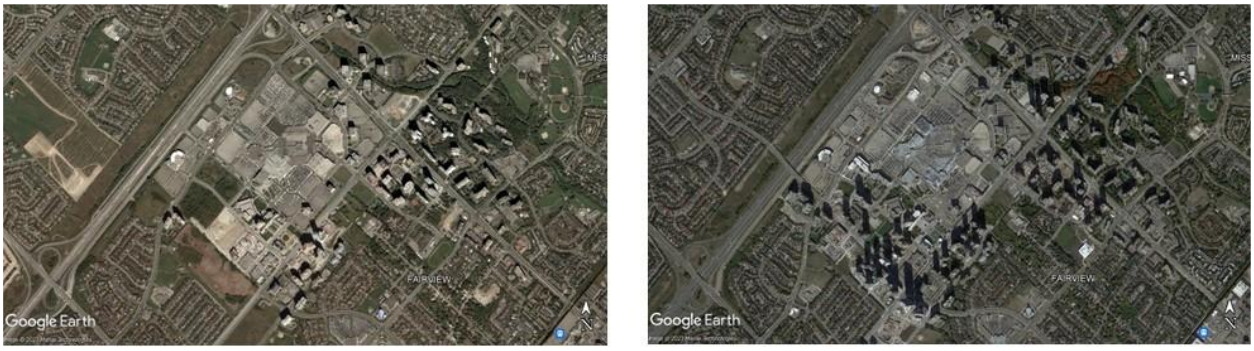


Figure 3-3 Map of Downtown Mississauga as per Downtown21 masterplan (City of Mississauga, 2010)

Downtown Mississauga has been undergoing a transformation from a low-density suburb with a large regional mall, to a mixed-use area with small-block streets (Allan & Campsie, 2013; Dardir & Berardi, 2021). In its initial vision, the centre was envisioned as a massive shopping mall placed in lush green spaces, where pedestrians and car realms were separated and pedestrians could move freely in a series of elevated walkways. Although the vision for a dynamic pedestrian realm and lush green spaces was never realised, the centric shopping mall has become the dominant feature of Downtown Mississauga, whereby the initial farmlands have been replaced by a large mall surrounded by extensive surface parking area. This car oriented mindset, in conjunction with the farmland street grid, resulted in a "suburban landscape void of vibrant urban life" (City of Mississauga, 2010).

The vision for the centre belonged to an era when suburban expansion was radiating from metropolitan Toronto and consuming the rural townships nearby. Accordingly, the Square One mall was proposed in 1969. The subsequent development included high-rise office spaces surrounded by large surface parking

area and residential condominiums in the tower in a park style. In addition, office/commercial and residential development zonings were separated from each other, forming large specialized districts that further increased car reliance. The Downtown witnessed rapid residential and commercial development, although office development has been stagnant since the 1990s due to cost concerns and parking constraints. Iconic development in this era included the new city hall and the large civic square built in 1987. This form of development belonged to an era before the principles of New Urbanism gained popularity. The New Urbanism began to be applied in the planning of Downtown Mississauga in the late 1990s and early 2000s. By this time, the employment development in Downtown Mississauga declined because the development in neighbouring suburban areas was less expensive and often allowed ample free surface parking (Filion, 2007). The current planning is guided by the Downtown21 masterplan, introduced in 2002 and revised in 2010, and is focused on improving pedestrian hospitability and attracting employment development.



(a) (b)

Figure 3-4 Progression of development in Downtown Mississauga, (a) 2004 and (b) 2023 (Google, 2023)**.**

Figure 3-4 shows the development progress between 2004 and 2023 period. Over the past two decades, the City has followed a range of initiatives to create a pedestrian friendly environment and achieve its intensification development target. This includes structured or underground parking (e.g. in the civic centre), relating new buildings better to the streets by bringing the facades adjacent to the sidewalks, creating street-oriented activities by shops and restaurants, and the expansion of the Square One mall toward the civic centre (City of Mississauga, 2010; Filion, 2007). Downtown21 has an exclusive focus on transforming the current urban area into a "downtown" urban built form. Accordingly, all the lands outside the Square One are designated for mixed land-use and. Moreover, large lots and parking spaces have been resized by removing limitations to the height and density, developing the multi-level transit, and providing urban amenities (City of Mississauga, 2010, 2013; Mississauga, 2016). The City has been

further focusing on the transportation network and an urban street grid. For this purpose, additional roads have been added to the current street grid to reduce the block sizes, improve accessibility to the neighbouring areas, and improve walkability. The City is also pursuing a Light Rail Transit (LRT) system, which is expected to improve regional and local transit use, and support other initiatives such as promotion of multi modal streets. Furthermore, the masterplan promotes mid-rise and high-rise mixed-use development with activated frontages near sidewalks to improve the range of activities for pedestrians.

Downtown Mississauga natural features include highly modified creeks and man-made green spaces. The green spaces are predominantly situated near its periphery, forming a ring-like distribution around the Square One mall and its surrounding office and parking lots, which remain devoid of green spaces. GI connectivity in the Downtown21 is addressed by connecting parks and open spaces in public and institutional lands through four corridors. These corridors include the Cooksville creek along Hurontario Rd, Mary Fix Creek and Zonta parks along Confederation Parkway, a connected network of small parks within the civic area (owned by the city), and a set of parks and street trees alongside Burnhamthorpe Rd. these corridors are depicted in Figure 3-5. The plan does propose street trees for the majority of the roads, but this intervention has not been implemented yet (City of Mississauga, 2010).



Figure 3-5 Location of the green spaces in Downtown Mississauga (City of Mississauga, 2010)**.**

3.2.4 Markham Centre

The area designated today as Markham Centre is located on the traditional territories of Indigenous peoples. The City of Markham acknowledges the commitment of the first nations to stewardship of the land. This includes the communities in circle, The North, West, South and Eastern directions, and Haudenosaunee, Huron- Wendat, Anishnabeg, Seneca, Chippewa, and the Mississaugas of the Credit peoples. The Dish with One Spoon Wampum Belt Covenant, a treaty between Indigenous nations, symbolizes a shared responsibility to sustainably care for the land. This area was once a fertile landscape of forests and wetlands, integral to Indigenous lifeways. Today, the Treaty Lands and Territory of the Mississaugas of the Credit include Markham Centre (Simpson, 2008; City of Markham, 2024). Located in York Region, north of the GTA, Markham Centre is the last suburban UGC, which emerged in the 1980s (Filion, 2007). This centre was initially planned for an area of 384 ha, framed by significant highways – Highway 7 to the north and Express Toll Route Highway 407 to the south – as well as the arterial roads – Rodick Rd to the west and Kennedy Rd to the east. Figure 3-6 compares the area between 1994 and 2020. The boundaries of Markham Centre have expanded twice since the initiation of the Growth Plan in 2006. Currently, it covers a total area of 494 ha bounded by Highway 7, Kennedy Road, Highway 407 and the Beaver Creek valley with some additions north of Highway 7 and east of Kennedy Road. These roads are

marked in Figure 3-6.

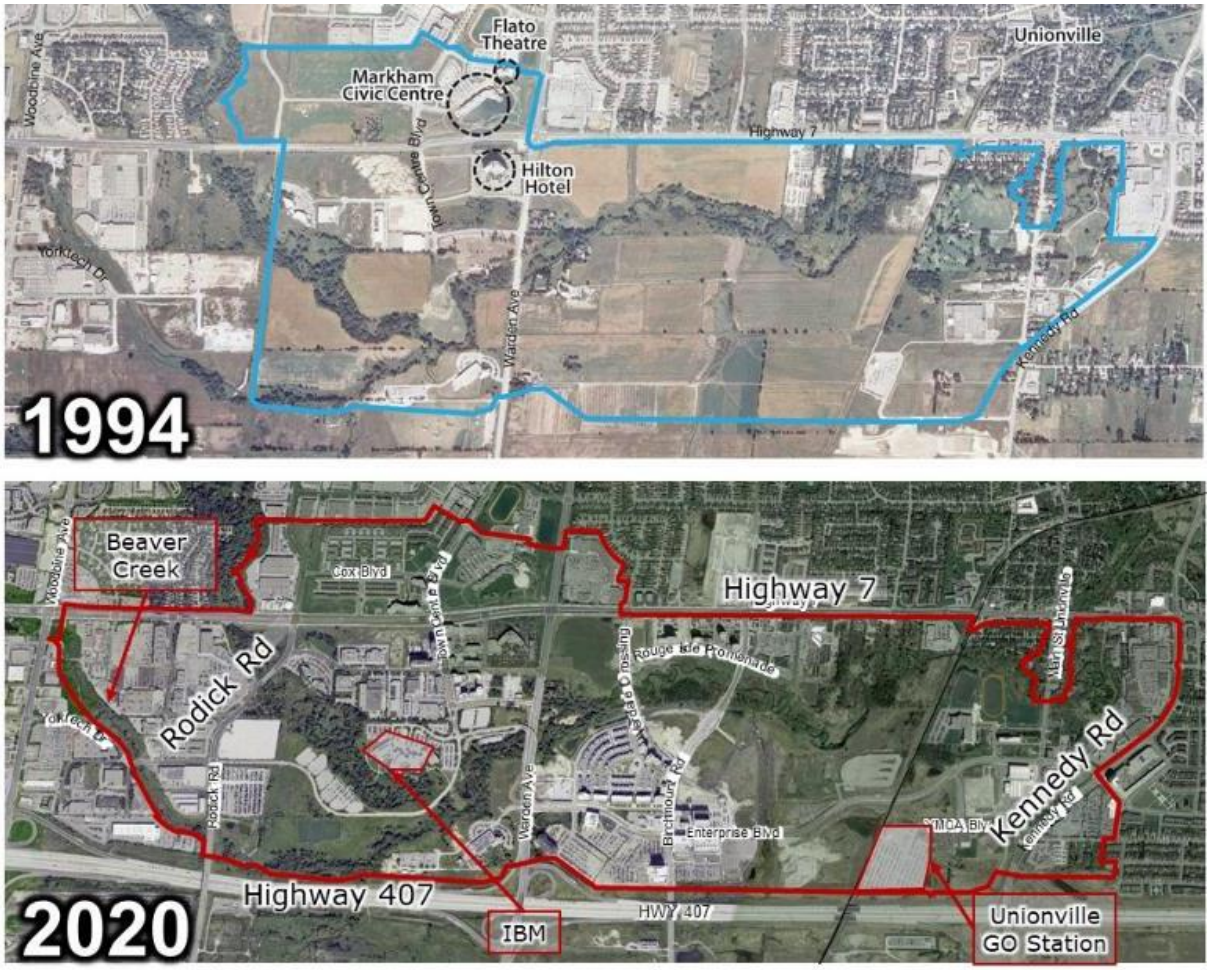


Figure 3-6 Expanding the boundaries of Markham Centre between 1994 and 2020.

Regarding the environment, similar to other UGCs in rural areas, Markham Centre essentially contains a strong component of the preservation of natural features and functions. Markham Centre contains a section of the Rouge Valley, the main branch of the Rouge River, which is an environmentally sensitive and protected area of the province. The Rouge River and its tributaries cover 22% of the area, passing diagonally through Markham Centre, and dividing the development into a few districts. To safeguard the water quality of the Rouge River, the portion of the river that passes through Markham Centre and its wetlands and woodlots are protected from development and are separated from grey infrastructure by legislated natural buffer zones. This creates challenges for intensification processes and reduces the available area for an integrated and unified UGC.

In terms of the built environment, there are significant landmarks in the Markham Centre, including the Unionville GO Station, Markham Civic Square, York University, Flato Theatre, the IBM campus, the Pan

Am Centre, major retail hubs, and cultural amenities. Markham Centre serves as a transportation hub due to its strategic location near Toronto. The connectivity to Toronto is enhanced by the presence of the Unionville GO Station and close proximity to major highways 7 and 407. Critically, Markham Centre's development commenced post-implementation of the Growth Plan in an area that was predominantly greenfield landscape as of the early 1990's, such that the city has had a "clean slate" for its intensification initiatives.

The City of Markham garnered valuable experience in New Urbanism through the development of the Cornell community, which has been extensively studied in planning research. Notably, the same design firm was responsible for the site plans of both Cornell and Markham Centre. Given that Cornell was developed prior to Markham Centre, the insights and expertise acquired from the former were instrumental in shaping the development of the latter (Perrott, 2020; Xu, 2017).

The current area of Markham Centre was initially farmland protected by the Provincial Parkway Belt West Plan. These lands were released in the 1980s from the provincial greenbelt lands. In 1992, the lands that had been locked during the planning and construction of Highway 407 were released. Ultimately, in 1997, the initial plan for developing high-density development, Markham Centre Secondary Plan (OPA 21) was approved. This plan followed the smart growth strategy, promoted new urbanism, relied on self-sufficiency, and included progressive sustainability goals since it belongs to an era of natural conservation (Filion, 2007; Kubursi, 2012; Veitch et al., 2013). The OPA21 has an ambitious vision for a vibrant/high-intensity urban hub and thriving economic focal point, where all amenities and activities are accessible for an excellent quality of life. Additionally, it had an exclusive emphasis on the conservation of natural resources.

By 2002, the eleven principles of the Markham Centre vision formed the foundations for a set of Performance Measures focusing on different domains, such as Greenlands, Built Form, Public Spaces, GI, and Transportation, which were used during the application approval process. These principles include protecting and enhancing the Rouge River Valley, supporting public transit, transforming Highway 7 into an urban boulevard, developing an effective street network, providing a "sense of place", enhancing pedestrian activity, ensuring ecological sustainability, providing cultural and social focus, managing traffic and parking issues, delivering a financial framework, and respecting quality of life in Markham (Markham, 2009a). The Performance Measures was later updated to be consonant with LEED Canada. Currently, the City fills the Performance Measures checklists and present consultations to improve the plans and proposals.

The development in Markham Centre ramped up after major employers, such as AVIVA and IBM started building campuses in the late 2000s and early 2010s. In addition, several strategies acted as catalyzers for attracting more companies and developers. For example, the City of Markham allowed temporary surface parking for the convenience of employment development, which were required to be replaced by structured parking over time. Other examples include public involvement and communicative strategies during proposal approval processes through Markham Centre Advisory Committee (i.e. formed by not only residents, but also major agencies and resident associations), which helped new developments to achieve the requirements of the Performance Measures. As another strategy for promoting development, the city lifted the building height limit imposed by the nearby Buttonville Airport.

In terms of planning documents, apart from the OPA21, an official masterplan for Markham Centre has not been finalized yet. However, a draft report, called Markham Centre Secondary Plan Update was released in 2020, which was followed by a development Concept Report in 2022. These reports indicate a shift from the initial intensification targets. They are attributed to the successful allure of developments, with current developer proposals for surpassing densities and building heights of OPA21. This development shift is also influenced by new public sector investments, such as the Pan Am Centre and York University, as well as the interest in transforming the Unionville GO station to a vibrant and mixed-use urban area (City of Markham, 2021, 2022b).

In terms of creating pedestrian environments, despite the new urbanist requirements, Markham Centre faces significant challenges. The vast area of the centre creates highly unpleasant and long walking distances between destinations. Secondly, new developments are done by a few developers in large scales, which has resulted in individual clusters of development with limited pedestrian connections. Furthermore, high speed and volume traffic on Highway 7 and the arterial roads create a hostile environment for pedestrians. Finally, the Rouge valley and its buffer zone creates further fragmentation between the clusters of development. To address these barriers, the new plans focus on developing a multi-tier transit system, trails, and amenities for pedestrians.

To protect the Rouge Valley, Markham Centre is divided into three areas of protected lands, development and a buffer zone between them. Development in the protected lands are not allowed and the buffer zone contains environmental restoration activities to minimize impacts of the development area on the protected lands. However, the City is facing challenges in terms of encroachments to the buffer zone as well as fragmentation of the greenway by roads, bridges, and other grey infrastructures. Therefore, Environmental Assessments are regularly performed on these crossings to ensure the minimum effect on the Valley. GI connectivity in Markham Centre is addressed largely in the form of the requirements for

new developments to achieve at least Leadership in Energy and Environmental Design (LEED) Silver status, as well as LEED for Neighborhood Development (LEED-ND). This specifies that the green spaces within new developments shall be connected. However, in practice, the majority of new developments in Markham Centre are comprised of multi-building/ neighbourhood scale developments, or 'development clusters'. The outcome of this type of development is that while GI networks exist within the developments, there is no plan for connecting GI elements between the development clusters. Therefore, GI in Markham Centre is dispersed by isolated patches of neighborhood development and the protected Rouge Valley in the middle. Similarly, in terms of pedestrian connectivity, although the development patches often have neighborhood scale pedestrian networks, pedestrian connectivity between the development patches is not consistent nor is it addressed in municipal policy (City of Markham, 2021).

3.2.5 Comparing the Planning Context of the Case Studies

The planning context of these two case studies differ significantly. First, the planning of downtown Mississauga predates the planning of Markham Centre. This resulted in the difference between urbanization approaches between the two centres. Downtown Mississauga has been planned around a large-scale regional mall and includes large surface parking areas of the mall. It was one of the earliest planning ventures for the creation of a multi-functional suburban centre. Markham Centre has been developed on green field land and followed sustainability narratives. Markham Centre is in York Region, a pioneer in GI planning. Therefore, although these case studies function in the same intensification-oriented planning system, they differ in their development stage, amount of protected natural land, environmental approach, and extent of adverse environmental consequences (Filion & Saboonian, 2019; Saboonian & Filion, 2019).

After selecting the case study locations, the data sources and analysis method will be described. The following section describes four main data source components: targeted literature review, plan reviews, interviews, and observations. Data gathering and data analysis methods will be discussed subsequently. As previously mentioned, these data components were collected and analyzed simultaneously, and the headings in the following section are not in any particular order. In other words, the data were gathered and analyzed in an interconnected manner, and the section headings do not indicate a chronological sequence.

3.3 Targeted Literature Review and Systematic Search

To start, the literature review was formalized by studying GI and intensification research literature. Prominent and well-referenced articles about stormwater management were studied. In doing so, it was

identified that stormwater management is a part of a holistic infrastructure, called green infrastructure (GI), which can be defined differently in rural, urban and natural landscapes. As this research seeks to investigate GI primarily as it relates to urban settings, GI articles that included urbanization keywords, such as “urban development”, “compact city”, “urban design”, and “smart growth” were reviewed. With regard to intensification, publications on “intensification”, “smart growth” and “compact city” as well as their environmental shortcomings (e.g. degraded air quality, urban runoff, and water pollution) were searched and studied. This “cross-search” approach identified a research trend between 2014 and 2019 that focused on the interdependence of “GI” and “compact city”. This body of research argue that in an urban context, GI and compact city models depend on each other and cannot operate in isolation. Thus, this research trend pursues the potential for simultaneous development of these models in a shared spatial context (Heins, 2015; Mittermüller et al., 2021).

During the literature review, an extensive body of largely empirical research about GI in intensified development was encountered. A systematic search was conducted to extract operational design tools, which could be applied in design proposals to illustrate interconnected GI and pedestrian networks. This process is described in the sections below.

The search method for the articles that were used in the systematic search method is different from searching for the literature review articles. The literature review chapter focuses on exploring the conceptual relationship between GI and intensification, while the systematic search method tries to address the empirical research that is useful for urban design and spatial/structural interactions between GI and the built environment. In the literature review, reviewed documents were identified by searching keywords such as green infrastructure and related terms (e.g., ‘greenways’), and intensification, ‘densification’ or ‘recentralization’ in the field of planning and design.

In urban areas, green and blue structures (e.g., trees, bushes, and lakes) that make up GI have the potential to provide a connected system of ecosystem services. However, as noted throughout this thesis, grey infrastructure with man-made or hard structures (e.g., buildings, roads, and utilities) interrupt the connection between the green and blue structures and thus reduce or block the provision of ecosystem services (Wurster & Artmann, 2014). While the provision of ecosystem services is the most significant value of GI for urban environments, the interaction between green/blue structures and grey structures determines how effectively the services are delivered. For example, trees beside high traffic roads in intensified areas exacerbate the impacts of air pollution because they block the air flow and trap the pollutants (Morakinyo & Lam, 2016).

Understanding the interactions between GI and grey infrastructure is critical for assessing how to integrate the two infrastructure systems together at the design level. In order to organize these interactions, a database was created. Since the objective of this dissertation is to work within the confines of intensification planning, the GI measures included in the database are specifically ones that can be developed in compact built environments. This unique database was developed to provide comprehensive recommendations that would not only reduce the adverse effects of intensification on the environment, but also enhance intensification goals with GI measures and, in turn, optimize the development of GI in compact cities.

In the targeted literature review for this research, it was found that numerous fields of study have conceptualized GI and have developed discipline-specific terminologies for it. Associated disciplines include urban planning, architecture, landscape architecture, ecology, engineering, urban forestry, law, and economics. A useful way of deriving information from multiple disciplines is the systematic search method, which is frequently applied in ecosystem services and GI research.

Systematic search is a research methodology that involves systematically reviewing and synthesizing findings from multiple studies in order to draw meaningful conclusions and identify patterns or trends across different disciplines or areas of study. For example, the systematic search method has been used to show that GI recedes urban runoff volume while reducing water pollution levels (Meerow & Newell, 2017). GI urban design is multifaceted from study areas, such as social science, environmental studies, and urban design. Hence, the systematic search method can assist in filling the urban design gaps of GI research by summarizing knowledge about the performance of GI in dense urban environments in multiple different fields of study (Bartesaghi-Koc et al., 2019; Haase et al., 2017; Hansen et al., 2019; Kumar et al., 2019; Mekala et al., 2015).

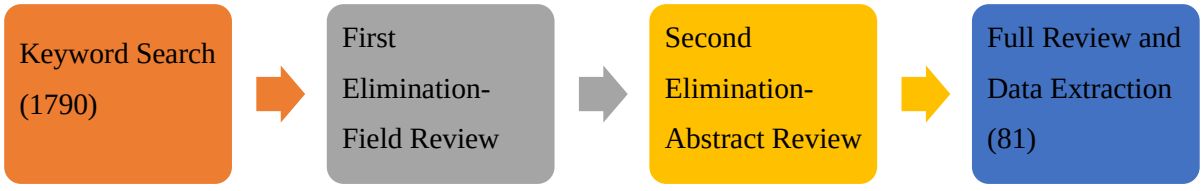


Figure 3-7 Systematic search steps taken in this research.

Finding the articles that were used in the systematic search includes four steps, as shown in Figure 3-7. In the first step, a keywords search is performed. This included identifying similar and interchangeable terminology using the logical operators “AND” and “OR” to derive the baseline database of articles.

Accordingly, three online citation databases were used: Google Scholar, Web of Science, and SCOPUS (Matsler et al., 2021). Although Google Scholar was used as the main tool, only the references that overlapped with the Web of Science searches were selected to ensure credibility of articles, limit the number of results, and use of logical operators in the search enquiries. Google Scholar was used as the main tool to identify terms that bear similarities in different fields. For example, LID and GI have been used interchangeably in the field of water and stormwater management (Matsler et al., 2021). SCOPUS was mainly used to track and use the most recent research. Searched terms included "green infrastructure", "low impact development", "water sensitive urban design", "sustainable stormwater management", "nature-based solutions", "semi-natural solutions", and "urban forestry" in the title, abstract, and keywords.

To limit the scope of search, these terms were searched in rotation (i.e. using logical operator "AND") with "urban development", "intensification", "recentralization", "densification", "compact city", "smart growth", and "downtown". Finally, the terms "ecosystem services", "benefits", "ecosystem disservices", and "service provision" were added. In addition, Google Scholar was used to search for each ecosystem services and compact city/intensification. This search resulted in 1,790 titles.

In the second step of finding articles for the systematic search, the articles that were irrelevant to this dissertation were filtered. Accordingly, the following characteristics of articles were screened: the research area, publication year, type, location of research, and languages. Regarding research area, some of the filtered words are popularly used in other disciplines. For example, "ecosystem" and "intensification" are common in civil and electrical engineering as well as material science. To sort according to publication year, the filtration process included only the articles of the past 10 years, when the concept of urban ecosystem services was initiated (Haase et al., 2014).

To select for type of article, the database was selected predominantly from peer reviewed journal publications, including review papers (to import insight from as many studies as possible) and technical/empirical papers (to include original works with verification support) for reliability of the publications. Therefore, book chapters and conference proceedings were excluded due to lack of verification and peer review processing, respectively. Two types of reports were also carefully selected using Google Scholar and added to the database: reports that were cited by numerous peer-reviewed journals and reports that are currently in use by international and national environmental organizations such as UN, EU, US-EPA, and Canadian EPA.

Research location was further filtered, so that only North American, European, and Australian contexts were included due to their similarities in planning regulations that are comparable to those of the case

studies' regions. Finally, the language of the research is limited to English for ease of study. However, bilingual publications are included (Ahern, 2016; Kowarik, 2021). The initial screening of the database based on the Metadata resulted in 130 relevant articles.

In the third step of finding articles for the systematic search, the abstracts of the remaining 130 articles were examined to eliminate three types of studies. First, studies that had a sole application in urban planning with little information about urban design were excluded. An example of a GI planning study that lacked detailed design details about GI measures and their environmental interactions was a survey involving 3,000 participants to understand their interest in conserving urban green spaces (Tian et al., 2020). As this article had little to inform GI design and planning, it was omitted from the article selection. Second, articles focusing on rural/agricultural or natural landscapes were excluded because of the lack of information about the production and/or reduction of urban ecosystem services. Third, research about arid or tropical environments was filtered due to the lack of similarity with the case studies.

Ultimately, 100 articles were selected to guide the creation of the urban design tabular tools. Each of these articles was screened for the following words: ecosystem services, interaction, ecosystem disservice, reduction, reducing, provision, production, service, structural, spatial, structure, and massing. The keywords were specifically chosen due to their direct relevance to GI in urban design, reflecting essential attributes of GI, such as ecosystem services, structural design, and urban interaction. The selection was grounded in a focused literature review, identifying terms frequently associated with GI-based urban planning. By considering the cross references, some citing papers were removed, and only original papers were kept in the database. This reduced the number of articles to 81.

The meta-data of these 81 articles (including the titles, keywords, locations, and abstracts) were coded and two major themes regarding urban design emerged. The first theme addressed the properties of GI elements (e.g. size, volume, height) and their implementation locations (i.e. UPOSs). The GI elements that can be developed in compact urban environments were categorized based on five structural properties: vertical elements, dependent structures, low profile structures, longitudinal structures, and spatial structures. The second theme dealt with the interactions between GI elements and the compact built environment. Once fully categorized, these 81 documents were read and analyzed in detail, and the segments relating to the two themes were coded. A summary of these coded segments are presented in tabular format in the Discussions Chapter (Chapter 4). This includes Table 4-2, "Spatial Classification and Description of GI elements" and Table 4-3, "Demand for Ecosystem Services in the UPOSs".

Planning Content Analysis

3.4 Record of the Planning Documents

Official plans, secondary plans (i.e. special plans for catalyzing the development of UGCs), and other planning documents that cover environmental and intensification aspects of urban development, were all examined as part of the present study. This included regional long-term plans, intensification strategic plans, and local secondary plans in UGCs. These documents provided information about planning models, urbanization practices, and environmental approach. As such, a list of reviewed documents is presented in Table 3-1. As suggested by relevant case studies, supplementary information from websites, internal reports, unpublished plans, and developer documents, were reviewed (Hansen et al., 2019).

In the plan review, information about GI and pedestrian networks was extracted. Any relevant information was recorded in a separate text file as a Microsoft Word document. This document will be referred to as the "Documents Database". This database was different from the systematic search database because it contained excerpts and comments, specifically related to the case studies and their planning context, and did not contain technical data about the GI measures. Three types of entries were extracted from the plans for inclusion in the Documents Database: text extracts; comments and interpretations about the text; and notes about the maps/pictures. Then short comments were added to different segments of the Documents Database to clarify their focus area. Any comments stemming from this sorting procedure will be referred to as "codes" (Creswell & Creswell, 2018).

This data was extracted in three steps. First, municipal policy and planning documents with a focus on intensification strategies and policies, environmental concerns and strategies, and transportation planning, were reviewed. Accordingly, a series of related terms were searched to explore existing knowledge of intensification and GI. This search included:

- Terms relating to GI and natural elements (e.g., wetlands, woodlands, parks, tree canopies, and individual GI elements).
- Terms relating to the practical role of GI in providing ecosystem services such as (but not limited to) stormwater management, and biodiversity.
- Instrumental terms that employ GI elements, such as "water systems".
- Terms relating to intensification (i.e. "intensification", "compact development", "compact city", "densification", "nodes", "centres", "nodal planning", and "recentralization")
- Terms relating to pedestrian networks such as "walkability", "pedestrians", "active transportation", "physical activity", "mixed use development", "activated facades", "complete streets", "pedestrian crossings", and "streetscapes".

Once this search was complete, indirect references to GI and pedestrian facilities were identified and the relevant sections were included in the database. For example, references to the Sheridan College Campus were recorded because this campus includes a range of GI interventions including green spaces, integrated pathways, and replacing surface parking with vegetated areas (Green Infrastructure Foundation, 2018).

Second, a comparison between the planning documents and planning theory (i.e. in peer-reviewed journals and books) of intensification, GI, and pedestrian oriented development was performed. The documents were searched for the related terminology to urban design guidelines such as building massing, street frontage, concept plans, street designs, building height cap limits, and land use policies. These data were compared with the planning principles of smart growth, intensification, new urbanism, and sustainable urbanization. For 'intensification', intensification targets and plans of case studies were searched. For environmental planning and natural-based solutions, the sections of the plans that deal with climate change and environmental issues such as the urban heat island effect, erosion control, and water pollution were searched. Furthermore, references to pedestrian networks, street networks, walkability, and pedestrian-oriented strategies were searched. The resulting data results were then entered into the database.

Third, the planned GI and pedestrian networks (i.e., proposed in the planning documents) were compared with the current state of these networks on the ground. This was done by comparing the spatial maps in the planning documents with the existing conditions shown in Google Earth satellite photos in order to identify any discrepancies between the plans and the chronological development of the UGCs (Bitting et al., 2018). Moreover, to verify the location and actual extent of GI features in the case study areas, the description of interventions in plans were compared with implemented interventions to find potential discrepancies. Additionally, the "historical imagery" feature of Google Earth was used, which has records available for the case studies since 2002, to study how these spaces have changed over time.

An example set of codes recorded by the author during the analysis of planning documents is as follows:

- "References to GI and even to "low impact development" were nearly absent in the initial provincial Growth Plan."
- "Regarding environmental planning, only directives for the protection of the Greenbelt and identified natural systems were introduced."
- "GI was mentioned only nine times in the updated version of Growth Plan, and exclusively in the context of stormwater management to reduce flooding risk in the case of climate extremes."

- "The use of the term "intensification" has slightly dropped from 57 times in the 2006 plan to 47 times while the use of the "complete community" term has significantly increased from only 9 times in 2006 to 25 times in 2020."
- "Complete communities" refers to mixed-use neighbourhoods with access to daily necessities, including employment, the choice of transportation, divers housing options and public service facilities, including recreation, health, educational and cultural services" (Ministry of Energy and Infrastructure, 2008; Ministry of Municipal Affairs and Housing, 2020a). (Zhang et al., 2015)

To conclude the planning principles of case studies, the textual data was searched for the related terminology to urban design guidelines such as building massing, street frontage, concept plans, street designs, building height cap limits, and land use policies. These data were attested by the planning principles of smart growth, intensification, new urbanism, and sustainable urbanization. The results were then combined with the analysis results from the interviews (described in the following section) to develop planning narratives of each case study.

3.5 Interviews

Interviews were conducted to explore municipalities' attempts to establish integrated GI and pedestrian networks. The interviews focused on participant perspectives of planning history and current condition of the sub-centres, major urban issues, implementation barriers for the existing plans, intensification strategies, current GI status of the sub-centres, and perceived future trends.

Interviews were conducted to gain context specific data about GI and intensification, to identify the current issues of promoting GI and intensification, and to explore further planning documents from case studies. Accordingly, the interviews complemented the planning documents by providing examples of the GI and intensification interventions, comments about the progress of the programs, and the obstacles faced in achieving the intensification targets.

Additionally, the interviews were intended to try and help identify how the centres and their plans were developed over time, while addressing the dominant forces that shaped current local plans for the sub-centres. The latter included momentous local features (e.g., highways and urban parks), historical events, and influential stakeholders (e.g. environmentally conscious governments, major developers, and large technological/industrial companies). These features are essential for developing narratives for each centre, and for a more thorough comparison of them (Tappert et al., 2018; Vecchio & Arku, 2020).

The interviewees were employees of the city of Markham and the City of Mississauga. They were subject experts, who had contributed to the development of planning documents and/or supervised relevant

projects in the case studies. They were selected based on their involvement and local knowledge in secondary plans, stormwater management, environmental/urban planning, urban design, and transportation infrastructure planning and design. The sample interviewees were mostly high-level managers and project leaders with diverse professional backgrounds. Having such a diverse selection of interview subjects enabled the broad identification of overarching issues and general themes that impacted the two case study areas.

Due to the provincial interest in intensification and the magnitude of development occurring, there was a significant number of employees involved in the planning, management, and urban design aspects of the UGCs. Therefore, it was not feasible to conduct mass interviews in the scope of this research. As a result, it was necessary to conduct selective sampling to choose the informants. The aim of the sampling was to interview a few informants with relevant information about both intensification experience and GI in the case study areas. Accordingly, I contacted individual departments by email and phone to identify key informants involved in GI and intensification planning. I identified two prominent employees at managerial levels, who lead the secondary plan development activities. Then, I used the snowball sampling method to identify additional interviewees, based on the input of initial informants (Lynch, 2019; Meerow, 2017). This selection also provided a wide range of perspectives into environmental shortcomings of intensification practice. The list of interviewees and their area of expertise are presented in Table 3-2. The interviewees were provided with the prepared questionnaire and given the choice of in-person, phone, or email interviews (Woodruff et al., 2022). All the informants agreed to in-person interviews except for one, who opted to complete the questionnaire and email it back.

Markham Centre interviews offered insights about the governance of this centre, which were not extractable from planning documents. Markham Centre did not have an updated secondary plan until 2020, when they issued an initial draft (City of Markham, 2020). The original secondary plan dates from before the Growth Plan, which was prepared in 1994 and approved by the Ontario Municipal Board in 1997. Since the Markham Centre needs flexibility in planning to attract new developments, the growth in the Centre is directed by a set of by-laws as performance measures. Performance measures require developments to meet a set of environmental standards. Over time, this led to the adaptation of LEED standards as a target for new developments. Information about performance measures was gained during the Markham Centre interviews.

In order to highlight underlying issues that the case studies identified for promoting GI and achieving intensification goals, interviews identified multiple challenges. Examples include ‘the need for surface parking lots to attract office development’ and ‘the single purpose approach to GI to deal with water

issues'. To explore additional planning documents, a set of plans and reports were either introduced during the interviews, or provided by the interviewees via email. These plans were in practice and consistent with the secondary plans, which are listed in Table 3-1.

Table 3-1 List of the reviewed documents

First round			
Document Title	**Government Level**	**Case Study Subcentre**	**Year**
Provincial Policy Statement (MMAH, 2020a)	Province of Ontario	All	2020
the Growth Plan (MMAH, 2020b)	Province of Ontario	all	2020
the Downtown21 (City of Mississauga, 2010)	City of Mississauga	Downtown Mississauga	2010
the downtown built-form standards (City of Mississauga, 2013)	City of Mississauga	Downtown Mississauga	2013
the 1997 Official Plan of the Markham Planning Area Amendment No.21 (OPA21)	Town of Markham	Markham Centre	1997
the Markham Centre Secondary Plan Update Vision Report (City of Markham, 2020)	City of Markham	Markham Centre	2020
example charrettes (Green Infrastructure Foundation, 2018; Green Roofs for Healthy Cities, 2015)	City of Mississauga	Downtown Mississauga	Various Years
stormwater management plans and business models (City of Mississauga, 2019; Mississauga, 2019)	City of Mississauga	Downtown Mississauga	2019
Ontario Ministry of Infrastructure. (2006). Growth Plan for the Greater Golden Horseshoe, 2006, Office Consolidation, June 2013.	Province of Ontario	All three	2006
Provincial Policy Statement, 2020	Province of Ontario	All three	2020
Growth Plan for the Greater Golden Horseshoe.	Province of Ontario Ministry of Municipal Affairs and Housing	All three	2020
Downtown21 Master Plan	City of Mississauga	Downtown Mississauga	2010
Etobicoke Centre Secondary Plan 1	City of Toronto	Etobicoke Centre	2017
Official Plan of the Markham Planning Area Amendment No.21 (OPA21)	City of Markham	Markham Centre	1994
Second Round			
Assessing the Centre	City of Toronto	Etobicoke Centre	-

Etobicoke Centre Public Space & Streetscape Plan.	City of Toronto	Etobicoke Centre	2011
Location : vision for the character	City of Toronto	Etobicoke Centre	2004
Making a Sustainable City Happen	City of Toronto	Etobicoke Centre	2006
Markham Centre Mobility Hub/Station Terms of Reference	City of Markham	Markham Centre	2011
Markham Centre Mobility Hub Study	City of Markham	Markham Centre	2013
Downtown Core Built Form Standards	City of Mississauga	Downtown Mississauga	2013
Downtown Core Local Area Plan	City of Mississauga	Downtown Mississauga	2016

The interviews were conducted based on a semi-structured questionnaire, which included a set of broad and open-ended questions, as well as GI and intensification specific questions (Palys & Atchison, 2014). The open-ended questions were then funneled to more specific and narrower structured questions. Palys and Atcheson (2003, p.165) suggest that interviewees will not respond well when they are asked many open-ended questions. Accordingly, the respondents were provided with a copy of the questionnaires and asked to select and prepare their responses, based on their choice and area of expertise.

Table 3-2 List of Interviewees and their occupations

No.	**UGC**	**Employment (Department)**	**Professional Remit**
1	Markham	Planning and Urban Design	Manager of Development for the Central Planning District
2		Policy, Development and Natural Heritage	Manager, Natural Heritage and Markham Centre Senior Project Coordinator Environmental Planning & Rouge Park
3		Engineering Department	Manager- Transport Planning
4		Policy and Research Section	Manager, Growth Management and Secondary Plans
5		Engineering Department	Senior Manager, Special Projects
6	Mississauga	Planning and Building Department	Manager, Downtown Collaborative Strategic Community Initiatives Division
7		Planning & Building Dept.	Project Leader, Green Development Standards Development & Design Division
8		Transportation & Works Department	Transit Planner, Business Development - Service Development
9		Community Services Department	Team Leader - Long Term Planning (Acting), Park Planning, Parks & Forestry Division
10		Community Services Department	Senior Planner, Pedestrian and Cyclist

To keep the interview transcripts manageable in size, I limited the length of the interviews between 1 and 1.5 hours. The interviewees preferred anonymity due to the critical contents of the interviews. Therefore, their names and specific information about their roles were redacted. Significant effort was devoted to transcribing the interviews. The textual data from the transcriptions was reviewed to identify the key themes of the municipalities' current approach to intensification. This includes the urban issues such as addressing large block sizes, lack of pedestrian environment, and green space shortage and scarcity. The themes also included the plans that address these issues, and the implementation barriers of the plans. The interviews also showed the views of the practitioners around environmental issues/GI development. An example of the questions and responses received is provided in Table 3-3.

Table 3-3 Example interview questions and the recorded answers.

Question type	**Question example**	**Response example (Specific to Mary Fix Creek Area)**
Broad questions	What are the natural features of the centre, and how have they been modified over time?	*"Cooksville Creek and Mary Fix Creek, They have been affected a lot across the City. Some creeks have been channelized whereas most have been piped and enclosed".*
open ended questions	How can we define the environmental dimensions of the center?	*"We have not yet developed quantitative measuring tools but e-Maps arerials may provide some insight on coverage (green, heat island, carbon footprint)".*
GI specific questions	Have there been decisions promoting green infrastructures in the centre?	*"Along Mary Fix Creek, particularly within the Downtown Core, the City has implemented a strategy to mitigate continuous flooding issues down the stream".*

Pedestrian environment questions	What are you doing to create a pleasant pedestrian environment? Why hasn't it been done before? What were the obstacles?	*"We have these large super-blocks. We tried to break them down into a fine grid of streets where we can and where feasible to encourage more walkability, more permeability, to help with the scale and access to built form and development pedestrian friendly, we have also a layer of parks and open space infused within this. We have to be really creative about the open space, not in the traditional form, but in ways of doing that through amenity spaces which we now other cities have started to be very innovative about"*

3.6 Direct Observations

Studying physical characteristics of GI networks and pedestrian networks through the direct observation method is popular among researchers because this method collects environmental field information. Direct observation methods often supplement other methods, such as interviews and plan reviews, to develop a well-rounded perspective on a problem. This method allows for the critical analysis of attributes of GI and pedestrian networks including inventories of street verge vegetation, identifying type of GI elements (trees, shrubs, and understory) and ground cover below vegetated areas (mulched or bare soil) (Hansen et al., 2019; Hunter & Brown, 2012; Marshall et al., 2019).

For pedestrian networks, there are existing audits that provide a long list of identifiable pedestrian network characteristics, such as the Irvine-Minnesota Audit (Su et al., 2019). Clarke et al., (2010) compare virtual audit methods (Google Street view) with in-person systematic observation audits of the urban environment, and find close agreement between these two methods. However, they argue that virtual methods have limited reliability for short-term characteristics of urban areas. For example, the existing conditions of buildings and streets may exhibit temporary characteristics such as broken window glass, cracking asphalt, or temporary traffic calming.

Virtual observation is done using free software packages such as Google Earth and paid packages such as Nearmap. Paid packages often use image processing to provide higher resolution. However, I used Google Earth because the resolution of Google Earth is sufficient for measuring the physical properties of urban areas, such as site area, sidewalk width, car lane width, and the distance between crosswalks (Venter et al., 2020). Therefore, using paid services provides no additional value.

Furthermore, while valuable, remote observation images cannot capture data about dynamic variables, such as GI condition and pedestrian experience (Clarke et al., 2010; Twardzik et al., 2018). Therefore, direct observation is needed to explore pedestrian variables, such as access to GI elements, traffic speed

and volume, sunlight exposure, and air quality. In addition, the remote observation tools have limited resolution. Therefore, direct observation was determined to be a critical tool for investigating GI conditions. Accordingly, both in-person site visits and remote visits though Google applications were used for data gathering (Anom & Sudarno, 2018; Bitting et al., 2018).

The observational data collection was informed by the interviews. During the interviews, the respondents referred to several locations that present specific issues of intensification and GI planning. They also identified several of their implemented interventions in the centres. This outcome of the interviews underscores the crucial role that site visits played in the research, enabling the examination and firsthand verification of interviewee statements about the case study sites. Thus, site visits conducted after interviews layered on further opportunities to gain insights into problems and solutions. Site visit data includes the state of development, and the current condition of GI and pedestrian networks in the case studies.

Along these lines, site visits are also complementary to plan reviews, because the visits can explore various aspects of case studies that are beyond the knowledge of planning practitioners (e.g. cultural ecosystem services provided by street verge vegetation for pedestrians) or overshadowed by the practice (e.g. use of GI for stormwater management overshadows its other benefits). Site visits also contribute to plan review by identifying existing conditions where proposed interventions in secondary plans have not yet been implemented (De Sousa & Ridsdale, 2021). These conditions are not easily evident in official plans and may be overshadowed in the interviews because of the bias of interviewees.

However, the data from direct observation is limited since not all the desired sites can be visited. Therefore, among the full set of possible site visits, a subset that reflects a diverse range of urban spaces and sites should be selected. This included streets with different geometries and vehicular volumes; sites without development (vacant lands), parks, or plazas; streets with commercial frontage; and areas with high-rise, mid-rise, and single-family development. Therefore, a few walking paths were selected, based on having various urban spaces and being within reasonable walking distance for the researcher. Accordingly, in-person visits were planned for a handful of sites. This included visiting Highway 7 in Markham Centre from Woodbine Avenue to Kennedy Road. A few cluster developments as well as a local residential road on the south side of Highway 7 were visited. In downtown Mississauga, four sites were targeted for visits: the area around the Square One mall, Burnhamthorpe Road between Hurontario Street and Confederation Boulevard, a stretch of Duke of York Boulevard, and Living Arts Drive.

These locations are also suitable for design proposals because of the expected transformation. Therefore, these observations inform the design proposal step by providing information about the size of the areas

available for GI integration, which will be used in selecting GI elements. The in-person site visits occurred at the same time as the in-person interviews (either immediately prior or subsequent to meetings) to minimise travel emission, time, and cost. Subsequent observations of the site were performed remotely, and yearly in-person visits were conducted to record the progress.

The data collected during the direct observations included photographs and field notes (Singh, 2016; Tamminga et al., 2020). Particular attention was paid to the interactions between GI elements, pedestrian facilities, and their surrounding environment. All the notes regarding GI and pedestrian networks were recorded. Although observations were intended to have a broad focus, a handful of questions were set initially as general guidelines for exploring the interaction between GI, pedestrian facilities, and their surrounding environment. Questions about pedestrian facilities include:

- What are the functionalities of each space?
- Who are the users of each space?
- Are the spaces used by pedestrians?
- Do the spaces provide pedestrian comfort?
- What are current frontages?
- Are the frontages activated?

Regarding GI, questions included:

- What are the present GI elements in each space?
- What are signs of GI connectivity?
- What ecosystem services are provided and what ecosystem services are missing?
- What are the eco-system disservices?

A few environmental characteristics were derived from the above questions to organize the field notes. Then they were updated iteratively by moving between the recorded notes and the environmental characteristics and comparing the notes taken for different locations. The final set of environmental characteristics included descriptions of urban space, structural/functional properties (i.e., how the pedestrian environment and GI elements could be described, and how these elements behaved), pedestrian experience, accessibility, and pedestrian nuisances. One example of field notes taken during visits to Highway 7 are shown in Table 3-4.

Table 3-4 Example of recorded field notes

Visit location & description	**Field notes**

Markham Centre- Highway 7- the portion of Highway 7 has 3 car lanes and bike lanes on each side, with dedicated bus lanes in the middle.	Structural GI- there are flowerbeds with plants separating sidewalks from the road. Covered with small trees and small plants
	Pedestrian nuisance - walking in the middle of the day. There is so much glare. It is also reflected from windows.
	Pedestrian experience- sidewalks are in good shape. They are covered in patterned tiles and are wide. You have to use the crosswalk to get to transit or cross the road. There are no shops nearby. There is a fenced vacant land on my side.
	Functional properties- there are no benches nearby and I have to walk a lot to get to the next red light. I did not have anything to do between the red lights. I did not see many people walking.
	Functional GI- there are no inlets to the flowerbeds. They are raised and do not collect rainwater. They are not connected to the storm drains.
	Structural GI- the vegetation on the flowerbeds is very short and does not act as barrier against the noise and pollution coming from the highway.
	Structural GI- There are wide green areas between the buildings and sidewalks. As a result, the building frontage floor is not activated
	Accessibility- it takes a long walk along the highway, the crosswalks are distant from each other and the wait times for the pedestrian light are long.
	Functional GI- the pavements are impervious and there is no sign that the stormwater is treated on site.

3.7 Data Analysis

To analyze the gathered study content, a coding strategy was applied. One database document was created to provide an overall sense of collected data including the notes of planning documents, transcribed interviews, and field notes from direct observation (Creswell & Creswell, 2018). To review the database,

the initial comments and codes reflected on the overall meaning of the information and the general ideas of individual sources. The coding process was done manually, which involved segmenting sentences or paragraphs of the database into categories and assigning a label to each category. The coding process applied Tesch's Eight Steps process as follows (Creswell & Creswell, 2018):

1. Reading the entire database to get a sense of the whole.
2. Reviewing the notes from secondary plans and writing about their meanings.
3. Making a list of codes and clustering similar ones.
4. Reviewing other segments of the database to either assign the codes from the list or create new codes for the segments without a code.
5. Finding short and precise words for each cluster of codes.
6. Refining the list and finalizing the name of the categories.
7. Rearranging the database by putting the segments with similar codes beside each other.
8. Reviewing the codes and recoding the segments to correct ambiguous codes.

The coding process aimed to generate the descriptions of studied urban spaces and the interventions. The coding process also produced analysis themes, which are general categories that bound a few codes together to organize different findings of the research. For example, the coded data associated with large block size and car-oriented development describes obstacles for achieving GI and pedestrian connectivity, which are categorized under the general theme of "barriers". As another example, analysing the plans reveals that most identified gaps for providing GI and pedestrian connectivity are associated with the lack of holistic urban design guidelines. Therefore, the topic of "gaps in developing design guidelines" was selected in order to address the connectivity of both GI and pedestrian networks (Creswell & Creswell, 2018; Duffhues & Bertolini, 2016; Raman & Roy, 2019).

The five identified themes are introduced here with more substantive articulations presented in the discussion chapter. The first theme discussed the built environmental problems of suburban development (i.e., large-lot size and car-oriented roads), which shaped the current approach of the case studies toward GI and pedestrian networks. This theme was presented as the barriers of developing GI and pedestrian networks. The data for this theme is gained from plan analysis and interviews, and the measurement capability of Google Earth.

The second theme shows the transformation process of the UGCs from suburban environments to multifunctional centres, which include GI too. This theme focuses on presenting the development of GI and pedestrian networks during this transition and includes a set of interventions that are derived from the

official plans. The content of this theme was extracted from plan review, supporting codes from the interviews and direct observations.

The third theme suggests locations where GI and pedestrian connectivity interventions may take place. This theme emerged when the coded segments were sorted based on the current interventions identified in plan reviews and interviews.

The fourth theme introduced four categories of UPOSs that can place the integration of GI and pedestrian networks in the UGCs. This theme covers clustering the codes for introducing the common spaces that can support the existence of GI and pedestrian interventions alongside each other. This theme presents data from the plan reviews and the interview codes, which were supplemented by the field notes about specific examples of GI and pedestrian integration in the UPOSs. This theme concludes that both GI and pedestrian interventions can exist in these identified UPOSs.

The fifth theme discusses the planning gaps of developing GI and pedestrian networks. This theme emerged by clustering interviewees' assessments about the current approach toward GI and pedestrian networks and comparing these codes between the two UGCs. Although financial limitations were mentioned by many of the interviewees, in order to reduce analysis variables and complexity, I decided not to focus on financial considerations in urban design interventions. Primarily, this research focused on the structural and spatial aspects of urban planning. Concentrating on these elements allowed for a more in-depth exploration of the physical and ecological aspects of GI integration without the variability introduced by financial factors. This approach ensures that the research outcomes directly inform design and planning practices, exploring structural and spatial configurations that best support GI and pedestrian networks, independent of budgetary constraints.

3.8 Design Proposals

Practical design in landscape architecture results in site-specific designs with limited intention for expanding landscape architecture and urban design knowledge. Studies suggest that the outcomes of research-based designs in the landscape architecture field can be design guidelines, design prototypes, and also detailed description of a set of lessons learned during the research (de Munnik & Lenzholzer, 2020; Lenzholzer, 2016). Accordingly, the outcome of this dissertation includes a set of design guidelines and multiple design proposals for both case studies, which illustrate the potential integration of GI and pedestrian networks in the identified UPOSs.

Design guidelines are one of the common outcomes of research-based designs in landscape architecture and urban planning. For design-based research, a valid methodology is 'research through designing'

(RTD), whereby the design is not a 'final product', but rather a means to expand the body of landscape architecture and urban planning knowledge (Nijhuis & de Vries, 2019). In RTD, the design is often followed by further work, such as obtaining feedback from various stakeholders (e.g., citizen groups and expert boards) and then updating the design through activities such as design charrettes until an optimal or satisfactory design is achieved. This makes it different from both research on design (i.e. study of existing designs and structures) and research for design (i.e. generation of quantitative scientific data to support evidence-based designing).

Lenzholzer et al. (2013) argue that to qualify design as academic research, it needs to address clear research questions, a theoretical framework, appropriate methods, and evaluation criteria. The design proposals in this dissertation address questions 3, 5, 6, and 7 presented in the beginning of the methodology section. The design proposals also support the theory of integrating GI and intensification. The methodology is appropriate because it uses the outcomes of the validated GI and intensification research, which was combined by the design experience of the author. The design proposals of this dissertation have accurate dimensions in their UPOSs though the measurement feature of Google Earth, which verifies the dimensions of UPOSs as well as the proposed integrated GI and pedestrian networks.

For the evaluation criteria, due to time limitations and financial constraints, this dissertation applied two types of verification. First, a verified database (e.g. peer reviewed journals, and internationally accepted reports) was used to generate the design tools and proposals. Second, Google Earth was used as a tool to verify the area of the proposals fit within the available UPOSs.

The design proposals take advantage of established guidelines from quantitative literature, which were extracted from published empirical work and organized in table form to inform planners and urban designers. To maintain validity, reference guidelines were only extracted from literature from geographic locations with similar hydrology and climate as Southern Ontario.

A set of sites were selected initially to describe the design process. The number of sites were reduced to three examples (one in each case study area), where a variety of the identified UPOSs exists to draw multiple conclusions and design guidelines. As a proof of concept, a site in Downtown Mississauga was chosen, which included all the UPOSs and the design proposal for this site is presented in the Discussions chapter. This site was chosen because of feasibility of the proposed interventions, potential connections to the GI in neighbouring sites, potential for creating pedestrian attractions, and the number of interventions.

3.9 Summary of the Methods

This chapter detailed the research methodologies of this dissertation, which demonstrated a systematic and academically rigorous exploratory sequential mixed method approach to answer the research questions and explore the core subject matter: the integration of GI and urban intensification. The methodology of this dissertation can be mapped across tree distinct but interrelated phases.

The first phase was a comprehensive compilation of targeted literature reviews, plan reviews, interviews, and direct observations, employed as qualitative methods to gather and synthesize information from a myriad of sources. This phase lead to conclusions about the current state of green infrastructure and pedestrian networks. The second phase was tasked with the generation of a pragmatic set of design tools that could be practically applied to support the implementation of an integrated GI and pedestrian network. The final phase involved the testing of these design tools, by applying them in design scenarios that illustrated how GI and pedestrian networks could be seamlessly integrated in different existing UPOSs.

This chapter's methodology was designed by selecting suitable research methodologies from two authoritative research design resources by Creswell & Creswell (2018) and Palys and Atchison (2014). Furthermore, a case study approach was applied using cases from the context of urban intensification in the GTA, providing both depth and breadth to the study and allowing for generalizable findings. Four types of data: targeted empirical research, plan review, interviews, and direct observation, were collected, systematically coded, and a trajectory for analysis was thoughtfully outlined. This analysis illuminated the emergence of four design-based themes for the integration of GI and pedestrian networks, and also uncovered common barriers, potential locations for integration, and gaps in planning and implementation related to these networks. A systematic search method was then employed to develop two design tools drawing upon the empirical works in the literature. Finally, this chapter delineated how these tools could be deployed to create urban design proposals, which could then be validated through measured assessments of the existing spaces.

This chapter serves as a rigorous blueprint for the research journey undertaken and illuminates the comprehensive nature of the process that has led to the findings and conclusions that will be discussed in subsequent chapters. With a focus on systematic exploration and rigorous academic approach, this methodology provides the necessary clarity and understanding of the complexity of the GI and urban intensification integration. The upcoming chapter will proceed with an in-depth discussion of the outcomes derived from the applied methodologies, presenting the results and discussing their implications in the broader context of GI and urban intensification.

Chapter 4
Discussions and Findings

In this chapter, the key findings regarding the multifaceted relationship between GI and urban intensification, specifically in the Southern Ontario context, are explained. The findings are presented in three parts based on the data analysed. In the first part, the findings from the targeted literature review are presented. This part starts by examining how GI fits into the modern urban design narrative, particularly how previous research approached the blending of GI and intensification and the shortcomings of the research in producing design guidelines to integrate GI and intensification, which are presented in sections 4.1 and 4.2. The findings presented in 4.3 suggest that UPOSs are unique in that they often host both GI networks, which are vital for ecosystem services, and intensification networks, which cater to pedestrian movement. These spaces are envisioned for achieving connectivity and multifunctionality for GI and pedestrian networks.

In the second part of this chapter, the attention is directed to the case studies, where the findings from analysing plan reviews, interviews, and site visits are discussed. Initially, the root causes for fragmented pedestrian and GI networks in the case studies are discussed in section 4.4. Then, the current efforts to address the connectivity for pedestrian and GI networks are presented in 4.5. Subsequently, the urban spaces for integrating GI and pedestrian networks are categorized in section 4.6. Finally, section 4.7 presents a critique of the current approach to urban design adopted by municipalities.

In the third part, the proposed design-based strategies, spotlighting key interventions that promise to enhance connectivity, making urban spaces more accessible and ecologically beneficial are presented. Accordingly, urban design tools are developed in section 4.8 using the findings from the systematic search data. Finally, the urban design tools and their implementation is verified through design proposals in section 4.9.

4.1 Previous Efforts for Blending GI and Intensification

Historically, the overlap between GI and intensification is seen in the debate between Landscape Urbanism (LU) and New Urbanism (NU). GI planning can be traced to LU while intensification has evolved from NU. While these two design movements are regarded as fundamentally at odds with each other in many ways, Heins (2015) argues that there is a common ground related to their focus on confronting suburban sprawl. They both have developed design tools, regulations, codes, and infrastructure that enable cities to address suburban issues (Heins, 2015). The common ground between

LU and NU, which existed historically, continues at present with using both GI and intensification to address environmental issues of suburban development.

This section reviews studies that discuss integrating green space planning, Green Infrastructure and compact city development, which can be considered the first efforts for blending GI and intensification (Artmann et al., 2019; Haaland & van den Bosch, 2015; Yuhong Tian et al., 2012).

4.1.1 Including GI in Compact City

In general, existing research discusses the integration of green space with compact cities from two perspectives: either it is approached from a design or planning perspective that focuses on integrating green space into new developments, or it is examined through a broader landscape ecology lens, looking at opportunities for green space connectivity on regional scales.

The first type of studies tends to review legal frameworks and strategic plans that mandate the inclusion of green spaces in new developments. This approach can be limited in that it fails to recommend solutions for green space scarcity in downtown areas and the loss of existing trees and green spaces due to in-fill development (Brunner & Cozens, 2013; Schäffler & Swilling, 2013). Frameworks developed in these studies can even perpetuate green space scarcity in downtown areas since they consider green space development more feasible, outside city cores (Haaland & van den Bosch, 2015; Tan et al., 2013). Furthermore, this body of research frequently focuses on developing specific types of GI (e.g. parks, green walls, or green roofs) on a site scale, and neglect connectivity between sites, thereby limiting green space scarcity in downtown areas GI functionality (Jim, 2012).

The second category of literature, coming from a landscape ecology perspective, starts with the ecological principle of connectivity to discuss the inclusion of green spaces in compact cities (Matsler et al., 2021). ‘Connectivity’ refers to the level of interaction between elements or organisms in a system or network, (Ahern, 2016; Davies et al., 2015; Hansen & Pauleit, 2014; Pauleit et al., 2011). As defined in the Introduction, a pedestrian network is a structure within an urban space consisting of interconnected streets, pathways, trails, and other pedestrian infrastructures (Jabbari et al., 2023). GI network here refers to strategically planned networks of natural and semi-natural areas interacting within an urbanized environment designed and managed to deliver a wide range of ecosystem services (Staccione et al., 2022). In urban ecology, GI is understood to be a collection of interconnected networks of natural and semi-natural features which facilitate this interaction (Beery et al., 2017; Jerome, 2017; Jerome et al., 2017; Puppim de Oliveira et al., 2022).

The goal of improving GI connectivity is to enhance GI's capacity to provide multiple functions (multi-functionality). A well connected urban GI is necessary for multifunctionality because provision of multiple ecosystem service benefits cannot be realized without a network aspect of green connections and corridors (Rusche et al., 2019). This approach creates connectivity between green spaces by linking core ecological areas to their surrounding buffer zones and corridors, such as greenways and riparian zones. One example design approach is the creation of "green fingers" that radiate outward from core areas and expanding greenbelts inward toward compact developments. However, this metropolitan or city-scale approach lacks a comprehensive GI typology that can be implemented in compact environments to assist with GI connectivity (Haaland & van den Bosch, 2015).

4.1.2 Co-developing GI and the Compact City

A new research trend advances the concept of including GI in compact cities, by encouraging the co-development of GI and compact city together. This novel approach, described by Puppim de Oliveira et al. (2022), argues that by studying GI and the compact city simultaneously focusing on their common sustainability principles such as connectivity and multifunctionality, there is opportunity for creating an ideal, 'smart' city that is both green and compact.

Artmann et al. (2019) developed an assessment framework that is intended to assess the extent to which cities are green and compact. This smart-compact-green city framework uses four characteristics: smart environment, smart multi- functionality, smart government, and smart governance. These four categories are comprised of 83 indicators for green and/or compact cities, 44 indicators for "green" characteristics and 39 indicators for "compact" characteristics. However, this assessment framework is limited in that it largely identifies end goals of co-developing GI and compact city, without providing implementation strategies to achieve them. Furthermore, this framework requires access to up-to-date and high-resolution data for analysis of indicators, which is often not available in city centres (Artmann, 2016; Artmann et al., 2017, 2019).

Finally, this particular smart-green-compact framework does not consider the spatial integration of GI and compact city. Although it describes the spatial aspects of GI and compact city through characteristics of smart environment and smart multifunctionality, it does not address urban form and scale of development. The authors further recognize that the framework does not deal with the spatial conflict between GI and compact city regarding competition over the land (Artmann, 2016; Artmann et al., 2019). A potential opportunity for addressing this spatial conflict is introduced in the next section.

4.2 Lack of Design in Previous Efforts for Blending GI and Intensification

Reviewing previous research in this section suggests that there is opportunity to integrate GI and compact city by focusing on their shared sustainability characteristics, particularly that of multifunctionality and connectivity (Artmann et al., 2017, 2019; Breuste & Artmann, 2020). In terms of the build environment, both GI and intensification focus on developing and redeveloping UPOSs to support their goals. The desired built environment of GI and intensification is defined by sustainability characteristics, such as multifunctionality and connectivity (J. A. Byrne et al., 2015; Hansen & Pauleit, 2014; Heins, 2015; Lo & Jim, 2010). Although UPOSs are clearly a key space for promoting connectivity and multifunctionality, few studies explicitly discuss designing UPOSs to achieve them.

The ways that GI and intensification consume space in UPOSs can manifest very differently, but many of their fundamental goals remain the same. For example, intensification promotes connecting walking and biking routes in UPOSs while GI seeks to re-naturalize UPOSs for ecological connectivity. While these intentional infrastructure designs are functionally exclusive, both have a shared goal of promoting healthy communities (Bolliger & Silbernagel, 2020; Tsegaye et al., 2019). In order to achieve connectivity for both GI and intensification, there is clear opportunity to develop design strategies that consider physical connections between landscape elements in GI and between urban destinations undergoing intensification (Connop et al., 2016; Meerow, 2017; Tsigdinos & Vlastos, 2020).

4.2.1 The Potential Blending of GI and Intensification through Connectivity

For both GI and intensification, connectivity is a spatial characteristic that can facilitate multifunctionality. GI connectivity contributes to GI multifunctionality by supporting the presence, distribution, and proximity of various GI elements in UPOSs, optimizing the provision of multiple ecosystem services in various urban areas. For intensification, connectivity means that urban infrastructure, public transportation, land uses, and public spaces are interconnected, which facilitates the movement of people within urban areas. The connectivity of intensified areas leads to multifunctional centres, where various activities are accessible to urban residents by public transit and active transportation (Davies & Lafortezza, 2017; Jim, 2012).

The following section reviews GI and intensification connectivity in the literature by focusing on urban design strategies. The purpose of this section is to further develop the concept of co-developing GI and compact city approaches through a connectivity lens (Breuste & Artmann, 2020; J. A. Byrne et al., 2015; Davies et al., 2015; Haaland & van den Bosch, 2015; Hansen & Pauleit, 2014; Kabisch, 2015; Schäffler & Swilling, 2013).

4.2.2 GI Connectivity

Historically, GI connectivity refers to a visibly continuous landscape of habitat patches and corridors, such as corridor-vistas in Versailles or forest and wetland patches in agricultural regions (Dramstad et al., 1996; Ignatieva et al., 2011). Now, GI connectivity is more broadly defined in the field of landscape ecology as ecological connections between landscape elements. Landscape elements can include many forms of patches and corridors, which are connected through wildlife networks, green belts, and the stepping-stone networks of small habitat patches and blue-green corridors. GI connectivity is essential for ecological processes that support biodiversity and ecosystem functions, which in turn are essential for human health and well-being (Lynch, 2018; LaPoint et al ., 2015).

GI connectivity provides biodiversity and ecosystem services by directly impacting the patterns and rates of species dispersal and materials' flow inside and between landscape elements, patches, and corridors (Artman et al., 2019; Davies et al., 2015). Habitat patches are multifunctional and nonlinear areas that have the capacity to support biodiversity, recharge aquifers, provide inhabitation and other resources for different species. They can include natural areas, such as forests and modified areas such as urban parks, ponds, and creeks (Lynch, 2018; LaPoint et al., 2015). Ecological corridors are linear areas of land cover, which not only provide habitat, but also conduct the movement of species, nutrients, and wind (Ahern, 2007; 2011). 'Stepping stones', or small-size patches close to each other, can include private gardens and individual trees and further serve as connective ecological corridors. When the connectivity of patches in fragmented landscapes vanishes, or the distances between these stepping stones become too great, each patch acts as a closed system and due to competitive exclusion, biodiversity and ecosystem services can be significantly reduced (Gillies & St. Clair, 2008; LaPoint et al., 2015; Loreau et al., 2003; Lynch, 2019).

Different Types of GI Connectivity

In landscape ecology, three types of connectivity between landscape elements are discussed: structural, potential, and functional. Structural connectivity refers to the physical connections between landscape elements, which depends on the spatial configuration of elements (proportion of land covered by vegetation) and patch density (number of patches per total landscape area) (Casalegno et al., 2017). Potential connectivity refers to the ability of an organism to move throughout a network and is dependent on the quality of structural connectivity. Functional connectivity describes the *nature* of the movement of organisms through a network, such as genetic flow and distributions between different populations of organisms (Iojă et al., 2014; Magle et al., 2009).

Structural connectivity is important for the provision of most ecosystem services. Although some ecosystem services that involve the movement of species are better defined using functional connectivity, for most ecosystem services, species movement is less deterministic than the physical connections between patches and corridors. For example, functional connectivity is important for pest control because the movement of predator species controls the population of vector species. However, applying a structural connectivity lens to the same example, if predator species cannot even access prey, pest control does not exist. As another example, the stronger the structural connectivity (physical connections) between riparian zones and creeks, the better they are able to reduce the flow rate of stormwater and mitigate flood risk (Delso et al.; 2019). The connectivity concept in landscape ecology is illustrated in Figure 4-1.

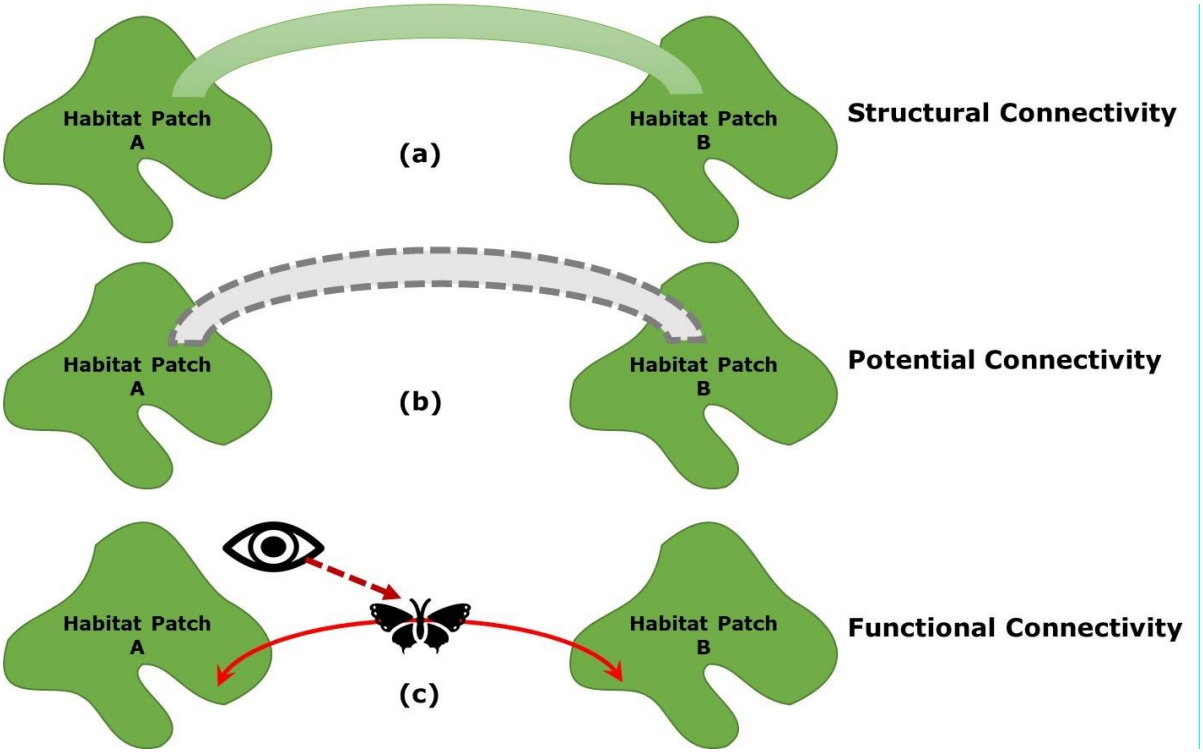


Figure 4-1 Different types of connectivity: (a) structural connectivity, where two patches are connected via a corridor, (b) potential connectivity, where organisms are able to move between patches, and (c) functional connectivity, where the movement of species is confirmed by observation.

Structural Connectivity for GI

In urban areas, GI connectivity is best evaluated in terms of structural connectivity, which refers to the intentional design and arrangement of GI elements to create a connected network that maximizes their

functionality and benefits. Structural connectivity of GI involves strategically linking various structural components of GI, such as parks, green roofs, street trees, and other green spaces, to form a cohesive and integrated network. Examples of GI structural connectivity include connected green roofs and green walls, urban tree canopy, street trees, greenways and linear parks. For instance, the structural connectivity of street trees can be found in Seattle, Washington, where the city has implemented a comprehensive Urban Forest Management Plan to promote tree planting and create connected tree corridors (Andrew Karvonen & Yocom, 2011).

Since the structural connectivity of GI focuses on spatial relationships between landscape structures, such as physical connection between urban parks and tree canopies, it can also be applied to the organization and layout of cityscapes. On an urban scale, the structural connectivity of GI is considered an essential component of functional connectivity since fragmentations in the structure of GI networks lead to interruptions in both the physical connectivity and functional connectivity of GI. These interruptions can result in the loss of the ecological functions, such as stormwater management, temperature regulation, and air quality improvement. Therefore, the structural connectivity of GI is the focus of the common practice in urban studies, which determine the potential and functional connectivity of GI as well (Penone et al., 2012).

The Importance of Design for GI Structural Connectivity

Although GI structural connectivity generally does not consider the ecological characteristics of species and is incapable of fully grasping the ecological functions of GI networks, it can act as an indicator for functional connectivity. This is because the movement of species and the flow of services depend on the physical connections between landscape elements. Promoting structural connectivity is achieved through a variety of targeted design strategies, such as developing greenways, reducing impervious surface, increasing vegetation coverage, daylighting creeks, and other GI interventions that can maximize the ecological functions of GI networks. Hence, providing design guidelines that encourage structural connectivity is crucial for improving the function of GI within urban environments (Correa et al., 2016; Zhang et al., 2019).

4.2.3 Intensification Connectivity

In intensification planning, intensification strategies such as mixed-use development, public transit, and active transportation corridors contribute to the connectivity of intensified areas (Davies & Lafortezza, 2017; Jim, 2012). Connectivity in intensified areas is primarily geared toward facilitating the movement of people through non-motorized transportation, (i.e., ‘active transportation’). The scale of development in intensification planning generally occurs on the scale of multiple neighborhoods so that associated

active transportation routes not only facilitate the movements of pedestrians, cyclists, and skaters but also assist transit users to reach local transit stations (Adkins et al., 2012; Berrigan et al., 2010; City of Mississauga, 2010; Rodríguez et al., 2008).

Walking is the most significant and favored mode of active transportation because it is a form of physical activity that does not require any equipment and skill (Lee & Buchner, 2008). The ability of pedestrians to walk and to reach their destinations in urban areas is defined by the structures that enable pedestrian movement. Pedestrian connectivity is the backbone of transit-oriented development in intensification planning, as transit stations need to be within walking distance to where people live and work (Rashid & Ara, 2019).

Pedestrian Connectivity

The quality of pedestrian connectivity is identified by potential connectivity, or the ability of people to walk to their destinations (Iojă et al., 2014; Magle et al., 2009; Radall & Beatz, 2001)). Both motorized and active transportation networks are defined by the characteristics of travel routes, such as the directness, diversity, and length (Randall and Beatz, 2001). For pedestrian movement, there are three general categories of factors that define the potential connectivity of pedestrian routes: physical environmental, social environmental, and individual factors (Verhoeven et al., 2017).

The physical environmental factors of pedestrian connectivity refer to the built environment features that impact walking. This includes the existence and quality of sidewalks, density of intersections, distance between destinations, and mixed-use lands. The social environmental factors of pedestrian connectivity refer to the two concepts of perceived walkability and the purpose of walking, which is related to the behaviour, preference, and perception of pedestrians. Perceived walkability refers to the degree to which pedestrians perceive an area to be walkable. Factors that influence perceived walkability could refer to safety of a given route, ease of reaching a destination, desirability or attractiveness of the pedestrian corridor, or distance to a given destination, among others.

Apart from the physical environmental factors, the motivation for walking, including walking for transportation (walking to destinations such as workplace or school), walking for recreation (jogging, walking for pleasure, walking the dog, etc.), walking for socializing (going to cafes or restaurants), and adventurous walking (meditative walking, stress relief, finding novel places, etc.) also determines pedestrian connectivity (Blečić et al., 2016; Rossetti et al., 2019). Individual factors of pedestrian connectivity define individual characteristics of pedestrians, such as demography and socio-economic class, which cannot be defined by design strategies. (Delso, 2019; Iojă et al., 2014; Lehto et al., 2013).

The Importance of Design for Physical and Social environmental Factors of Pedestrian Connectivity

For both physical and social environmental factors of pedestrian connectivity, design features are significant. Examples of such features might include the topography of streets (i.e. street slope and sidewalk proportions), street and neighborhood elements (e.g. street lighting, architectural attractions, protected or abandoned buildings); and the green features of streets (e.g. tree canopy and street verge vegetation). Design features directly impact quality and visibility of physical environmental features, while they indirectly influence social environmental factors of pedestrians, such as perceptions of safety, crime, social disorder, and social engagement. For example, a lack of barriers or guards between sidewalks and automobile traffic can reduce pedestrians' perception of safety (Blečić et al., 2016; Giles-Corti et al., 2011; Lu et al., 2018; Rossetti et al., 2019). At the other end of the spectrum, design features can enhance land-use, density, and transportation characteristics for pedestrians. For example, designing mixed-use neighborhoods can increase the appeal of the built environment for pedestrians and make outdoor areas more active (Gidlow et al., 2010; Institute of Medicine & National Research Council, 2013).

4.2.4 Similarity between GI and Pedestrian Connectivity

While some studies focus on connectivity as a spatial characteristic exclusively for the purpose of incorporating GI in compact urban environments (Artmann et al., 2019), other studies investigate the correlation between GI networks and pedestrian networks for improving walkability. These studies argue that examining pedestrian connectivity through the lens of landscape ecology can assist with designing pedestrian networks because they are both defined by similar traits. GI connectivity is described by integration, quality (or attractiveness), and proximity of landscape elements (habitat patches and corridors) while pedestrian connectivity is acknowledged by density, attractiveness, proximity, and concentration of pedestrian routes and destinations (Delso et al., 2019; Galster et al., 2001; Ryan & Frank, 2009).

Pedestrian connectivity and GI elements can both be defined by habitat patches and corridors. Pedestrian destinations are equivalent to habitat patches with elements such as paved surfaces with enticing physical features for pedestrians, including commercial identities (Ewing et al., 2016), natural settings (urban trails) (Ermagun et al., 2018), urban greenery (Tamminga et al., 2020), and urban amenities (Guo and Loo, 2013) comprise pedestrian corridors. The examples of pedestrian corridors are pedestrian-dominated streets (Ewing et al., 2016) and multi-use trails (Craige and Ataee, 2015). GI corridors in urban areas are

generally identified in the form of riparian zones (Kondolf and Pinto, 2017), linear parks (Park and Lee, 2019), and tree-lined streets (Firehock and Walker, 2015).

For GI connectivity, due to limited available UPOSs for developing GI corridors, 'stepping stone' patches are an alternative to GI corridors, as they can be spatially discontinuous while functionally connected. Although GI corridors are most effective for the movement of species and the flow of nutrition, stepping stone spaces are valuable for natural conservation because, in fragmented landscapes, they provide alternative routes connecting multiple patches. Examples of GI stepping-stones include distanced trees, vacant lots, or home gardens, which are close enough to support the movement of species and the conduction of nutrition through direct links (e.g, water conduction through bioswales) and indirect links (e.g., the dispersal of ruderal species through wind) (Zhang et al., 2019).

The corridors of both GI and pedestrians not only connect their habitat patches but also act as habitat patches in and of themselves. GI corridors can serve as small habitats for different species of wildlife, such as birds, insects, or small mammals. Similarly, pedestrian corridors can facilitate movement and serve as destinations for pedestrians with different intentions for use, such as relaxing, eating, reading, and exploring (Ignatieva et al., 2011; Ortega et al., 2015). Despite their similar characteristics and functions, potential design guidelines to improve corridors for both GI and pedestrian connectivity are understudied. Importantly, there is a significant opportunity for GI elements to assist in creating pedestrian-oriented environments which has been absent in the research to this point.

4.2.5 Design Opportunity for GI and Pedestrian Connectivity

While UPOSs present significant opportunity for developing habitat patches and corridors to achieve GI and pedestrian connectivity, the current literature does not adequately address design guidelines for UPOSs to achieve these goals. To improve GI connectivity, current literature focuses on two predominant design solutions. The first involves connecting large habitat patches to safeguard significant GI features at a regional or landscape level (Snäll et al., 2016; Van Teeffelen et al., 2015). The second approach promotes connecting small urban patches to improve the provision of stormwater management and recreational ecosystem services for urban residents (Magle et al., 2009; Meerow, 2020). There is a distinct absence of clear design directions for GI connectivity in UPOSs on one neighbourhood or multiple neighbourhoods' scale.

For pedestrian connectivity, current design methods recommend increasing the density of street networks (the quantity of direct and indirect connections between the two points) and improving the layout of streets. The former increases the physical continuity of pedestrian routes along existing streets, and the

latter encourages walking by reducing obstacles and distances for pedestrians. For instance, short blocks and grid-like structures reduce pedestrian obstacles while cul-de-sacs and long blocks increase pedestrian distances (Berrigan et al., 2010; Dill, 2004; Handy et al., 2003).

However, some studies emphasize the importance of designing UPOSs for pedestrians and question the positive relationship between street connectivity and pedestrian connectivity when streets have been originally designed for cars. These studies highlight potential for UPOSs to improve pedestrian experience and provide a better quality of connections for active modes of transportation, such as walking and biking (Lu et al., 2018; Masoud et al., 2019). For example, Broach et al. (2018) question the value of street grid patterns for pedestrians and highlight the importance of parks, recreational trails and schools for providing pedestrian pathways (Masoud et al., 2019). However, designing UPOSs for improving pedestrian connectivity on large scales, such as multiple neighborhoods' scale has been rarely addressed in articles.

The targeted literature review revealed that a lack of design guidelines and space provisions are significant problems for GI implementation. At the same time the review of articles that focus on intensification, smart growth, and compact city themes, revealed that there is an absence of space provision, design for public spaces, and walkability in intensification planning. Based on the literature review conducted, the methodology utilized by the current research study challenges the existing approaches of GI and intensification planning by addressing GI and pedestrian connectivity performance.

4.3 Finding Common Ground between GI and Intensification

4.3.1 The need for integrating GI and intensification

The Similar Sustainability Aspect of GI and Intensification

The literature review demonstrates that from a broad perspective, GI and intensification planning try to improve similar sustainability aspects of urban areas: the urban life, urban efficiency, and the urban environment. However, the two planning models define these three aspects from different points of view and address them by promoting different strategies. Both GI and intensification contribute valuable perspectives to achieving urban sustainability. Indeed, under each category of urban life, urban efficiency, and urban environment, the sum of GI and intensification goals can address more sustainability issues of urban areas than when each is implemented exclusively. For example, promoting active transportation in the intensification planning combined with attention to GI planning for environmental health, can lead to an overall healthier lifestyle and living environment for urban residents (Artmann et al., 2019; Heins, 2015; Tappert et al., 2018).

Overlapping Policies of GI and Intensification for UPOSs

As seen in the literature, the common ground between planning and design for GI and intensification is evident in their overlapping policies about developing urban and public open spaces (UPOSs). For each urban area category, the UPOSs are the main spaces that can contain both GI and intensification strategies. For example, for the urban efficiency category, intensification targets UPOSs for promoting public transit while GI consumes UPOSs for developing visible infrastructures, such as urban ponds and urban gardens. This highlights the opportunity to integrate new public transit corridors with visible infrastructures (Panagopoulos, 2019; Sikorski et al., 2018).

Addressing Equity

In the context of urban planning, the concept of Equity focuses on fairness and addressing the specific needs of diverse groups of urban dwellers. Equity aims to provide resources and opportunities based on people's circumstances to achieve fair outcomes. This often translates to redistribution of resources to address infrastructure imbalances. Examples may include prioritizing investment in neighborhoods that have been under-resourced or exposed to environmental harms like pollution or flooding. Equity for urban planners often translates to creating inclusive and sustainable cities by addressing the unique needs of different communities. This is particularly important in high-density environments, where competition for land can exacerbate disparities in access to natural resources and recreational areas (Zuniga-Teran et al., 2020, Gibson et al, 2019).

The concepts of equity and equality are often conflated while they are distinct concepts. Equality implies treating everyone the same. However, it sometimes overlooks the differences and specific needs of disadvantaged groups. Equity involves recognizing and addressing those differences to ensure fair outcomes. In the context of urban design and sustainability, equity is not just about equal access to urban resources but ensuring that people from all backgrounds have the necessary opportunities and support to benefit from those resources (Talen, 2010).

Equality in urban planning may involve providing access to similar parks across the city. However, in intensified areas, this approach is not ideal due to limited space and higher population density. (Tan et al., 2013)., In intensified areas, everyone may have access to a park, but the quality and experience of that access differ because the number of residents per park would far exceed what these spaces can accommodate. This undermines the intended benefits. Here, equity focuses on ensuring that everyone, in intensified areas, has access to necessary ecosystem services, regardless of space limitations.

In this study, equity is addressed by providing access to ecosystem services through a specialized, connected network of GI and pedestrian environments in UPOSs. In contrast with replicating large and uniform parks of suburban areas, the proposed design for intensified urban areas focuses on multifunctional spaces that serve the specific needs of high-density communities. Importantly, high-quality GI measures are often developed in higher income neighborhoods, which limits the provision of ecosystem services for the residents of those communities. At the same time, the focus on pedestrian connectivity further supports equity by making urban areas more accessible and livable for those who does not have access to urban services by cars or active transportation equipment, such as bikes and skates since walking is the simplest type of active transportation and does not need any skills and equipment. Developing accessible GI and walkable environments for all communities promotes health and well-being in different social groups including disadvantages communities. The integration of GI elements, such as green roofs, permeable pavements, and street greenery with pedestrian pathways ensures that residents, regardless of their socioeconomic background, benefit from ecosystem services such as air purification, stormwater management, and enhanced walkability. This allows for a more effective and fair distribution of resources for all urban residents, regardless of the spatial constraints.

4.3.2 Current Approach of the Literature for Integrating GI and Intensification

Connectivity as the Key for Integrating GI and Compact City

To find opportunities for integrating GI and intensification, studies have started comparing the similar characteristics of GI and the compact city against each other. Both GI and intensification, like other sustainability planning models, are described by similar sustainability characteristics, including connectivity and multifunctionality. Multifunctionality describes the overall approach of GI and intensification. GI as an urban infrastructure can provide multiple functions in urban areas while intensification develops urban centres with the concentration of multiple activities. To achieve multifunctionality, the built environment of GI and intensification planning should be driven by the spatial characteristics of connectivity, accessibility, proximity, and others. Connectivity is in the core of designing for GI and intensification and it can improve other spatial characteristics. For example, creating connectivity through pedestrian corridors can result in increasing the proximity of pedestrian destinations to where people work and live. GI connectivity, for instance, results in the increased number of GI corridors across urban areas, which reduces the distance to green spaces for residents and improve the provision of ecosystem services for them (Filion & Saboonian, 2019; Hansen & Pauleit, 2014).

The Common Ground of GI and Intensification

Three types of structural, potential, and functional connectivity have been described previously, in the context of landscape ecology. At the urban scale, GI planning focuses on structural connectivity, achieved through a linkage of natural and semi natural features. It is applied in the context of urban design, because it discusses the spatial relationships between landscape structures (Casalegno et al., 2017). For simplicity, this study refers to GI structural connectivity as only GI connectivity.

For intensification, pedestrian connectivity is the backbone of all alternative modes of transportation. Pedestrian connectivity is investigated by potential connectivity through the potential ability of pedestrians to move and to be connected to their destinations in the urban context. Hence, it has a significant contribution to the intensification policies of promoting active transportation and public transit (Iojă et al., 2014; Joh et al., 2015; Magle et al., 2009).

Recent studies discuss pedestrian connectivity from the lens of landscape ecology, and argue that it can be described in a similar structure. Pedestrian connectivity connects pedestrian destinations (or in the GI language, habitat patches) through pedestrian corridors, which supports the movement of pedestrians and promote active transportation. The structural connectivity between GI elements (habitat patches and corridors) link small and large habitat patches, which facilitates the movement of species and the flow of nutrition in a large-scale urban environment. This supports the provision of ecosystem services and biodiversity as the primary goal of GI planning (Delso et al., 2019).

4.3.3 Similar Spatial Objectives of GI and Pedestrian Connectivity

This study argues that based on the literature review, as GI and pedestrian connectivity can be described as having spatially similar structures, their respective components have the potential to bolster each other's spatial objectives. GI connectivity and pedestrian connectivity can enhance each other's goals as GI can be part of pedestrian features and pedestrian routes can organize GI elements. For GI, linear UPOSs are the traditional form of greenways in downtown areas, encompassing rivers, public trails, and railways to address multiple planning goals, including economic and recreational ones (Benedict et al., 2006; Kambites & Owen, 2006; Marcucci & Jordan, 2013). For pedestrian networks, the natural and semi-natural features of GI are important physical features that encourage walking and other forms of active transportation. Developing GI elements in pedestrian habitat patches and corridors also reduce the harmful impact of intensification, such as the loss and fragmentation of natural habitat (Tsai et al., 2019).

At the same time, developing GI in pedestrian corridors brings urban dwellers into proximity with nature so that GI elements can provide essential ecosystem services for humans. In addition, the linear urban spaces of pedestrian networks, including sidewalks and urban plazas can provide space for the GI development in areas under intensification (Di Giulio et al., 2009). Developing GI and pedestrian

connectivity simultaneously is spatially more efficient than developing these in separate spaces. One example of developing GI and pedestrian connectivity in shared UPOSs is the twelve greening projects in Boston, USA. These projects include pocket parks, street edge gardens, and street trees, which are used to connect six large parks to enhance bird diversity while accommodating pedestrian features such as seating areas with benches, trails, and playgrounds (Lynch, 2019; Strohbach et al., 2013).

4.3.4 Means of Blending GI and Pedestrian Connectivity in Intensification

This section explores potential ways of integrating GI connectivity and pedestrian connectivity in the context of intensification. It looks at the two case studies of Downtown Mississauga and Markham Centre, the two UGCs (Urban Growth Centres) located in Southern Ontario, Canada to explore the barriers and opportunities of developing GI and pedestrian connectivity from a planning and design point of view. It is followed by studying the provision of GI and pedestrian connectivity in the case studies, identifying potential UPOSs for the integration of GI and pedestrian connectivity, and exploring the design-based gaps of municipality plan in capitalizing on for such opportunities. Ultimately, a set of design guidelines is prepared to address these gaps through integrating GI and pedestrian connectivity in shared UPOSs under pressure by intensification.

The Common Space for GI and Pedestrian Connectivity in the Intensification planning

From the lens of landscape ecology, on an urban scale, the structures of networks should be composed of nested elements in broad landscapes so that they can function on multiple scales. Hence, the provision of space for connecting the elements of networks (habitat patches and corridors) throughout an urban landscape is crucial. As the literature review suggests, GI and pedestrian connectivity are both developed in UPOSs. However, due to space scarcity, these two are forced to share UPOSs, which can lead to a conflict in network connections where one type of network is prioritized over the other (Delso et al., 2019).

Lack of Design Guidelines for Developing GI and Pedestrian Connectivity

Although GI and pedestrian connectivity have become essential parts of urban planning, in areas under intensification, there is often a lack of planning and design guidelines for developing them due to space-consuming build-up of housing, commercial and workspaces. For pedestrian connectivity, studies highlight that designing high-quality environments should rely not only on grey infrastructure measures that act as physical environmental features of pedestrians, such as human-scaled facades and urban furniture but also GI measures, such as street trees, streams, and green walls, which provide safety and attractiveness for pedestrians (Kondolf & Pinto, 2017). However, the focus of intensification design is on

promoting the physical continuity of pedestrian networks by retaining sidewalks and creating new ones along streets (Lu et al., 2017). Hence, promoting safety and attractiveness to better facilitate the needs of pedestrians exists only in guidelines and is often cast aside in situations where budget and physical space are limited (Brown et al., 2007; Coutts et al., 2019; Novak, 2019). In addition, designing for different purposes of walking is not prioritized although studies and design guidelines recognize that pedestrian routes should contain different activities for pedestrians, such as exercising, reading, and eating (Rembeza, 2017; Zwierzchowska et al., 2018).

For GI connectivity, integrating GI elements within grey infrastructures relies on an adequate knowledge of ecosystem services and biodiversity. However, there is a dearth of studies that promote tools and strategies to support integrating GI with grey infrastructure measures, including pedestrian infrastructures. Current literature mostly discusses the assessment of existing GI and does not fully address the required comprehensive design guidelines and planning regulations for creating new ones. Although scientific data in the literature presents how location, extent and vegetation type of GI can support ecosystem services and biodiversity, there is a lack of design recommendations for developing GI elements in tandem with grey infrastructure to support ecosystem services and avoid ecosystem disservices (Roman et al., 2021).

As this dissertation focuses on blending GI and intensification through integrating GI and pedestrian connectivity, this chapter discusses the barriers and potentials of developing these two in areas under intensification through a comparative case study. The aim is to address the lack of design guidelines for developing GI and pedestrian connectivity in intensification planning by dealing with the barriers and using the potentials of integrating GI and pedestrian connectivity. The following section discovers the built environmental barriers of developing GI and pedestrian connectivity in areas under intensification. Recognizing these barriers is essential to discover both the strengths and gaps of case study municipalities to address these barriers.

4.4 Barriers to Developing GI and Pedestrian Connectivity in Intensified Areas

Historically, suburbanization does not prioritize planning and design for GI and pedestrian connectivity so that these networks are highly fragmented by the dispersed and car-oriented built environment. In Southern Ontario, intensification is occurring rapidly in suburban areas, which were originally planned to facilitate the movement of cars. As intensification occurs, other urban infrastructure, such as buildings, green spaces, and active transportation measures are added to the existing car infrastructure through incremental interventions in municipality plans. The lack of a comprehensive approach to GI and pedestrian planning and design during intensification results in a patchwork of interventions spread throughout the city. Lack of comprehensive planning creates discontinuities between the elements of GI and pedestrian infrastructures, which, in general, is referred to as urban fragmentation. Several studies discover the impact of urbanization on greenways and environmental corridors (James & Archana, 2013). At the same time, studies, such as Di Giulio, 2009, demonstrate that urban fragmentation decreases pedestrian connectivity and increases walking travel time.

A lack of planning and design for GI and pedestrian connectivity leads to the failure of GI and intensification planning goals. To discover ways to avoid this failure, this section identifies the barriers to developing GI and pedestrian connectivity in areas under intensification. Interviews, planning documents analysis, and direct observation of case studies show that in UGCs, large-size urban blocks and car-dominated roads are the main barriers to developing GI and pedestrian connectivity from the built environment perspective. Large-size urban blocks refer to the sizable parcels of land characterized by their significant physical footprint and expansive dimensions, often accommodating space for farms in farmlands and single-family homes, gardens, landscaping, and recreational activities in suburban areas. Car-dominated roads are the roads that are devoted exclusively to cars, which can create environments that are perceived to be hostile to active transportation. As UGCs are being developed in originally suburban areas, these are shaped by car-dominated roads and large-size urban blocks, which constantly interrupt the elements of GI and pedestrian networks and occupy the potential space of their habitat patches and corridors (City of Mississauga, 2010; Filion, 2003; Ministry of Municipal Affairs and Housing, 2019; Searle & Filion, 2011). In this section, a synthesis of findings from the interviews is presented. Then, the findings from all resources are used to identify the underlying obstacles to achieving connectivity during the intensification of suburban areas.

4.4.1 Summary of the Interview Findings

The interviews provide a first-hand understanding of the challenges the municipalities face during the intensification of UGCs. This includes developing urban planning strategies, prioritizing interventions,

and implementing them. This section synthesizes the primary findings derived from the interviews, emphasizing the key themes of transit-oriented development, sustainability, urban growth challenges, and community collaboration.

Employment and Economic Incentives

During the interviews, it became clear that increasing job density is more challenging than increasing residential density. Both cities have strategized attracting employment and provided economic incentives. Interviewees from both cities recognize the role of commutation for employers and are committing to provide surface parking as well as alternative mode of transportation infrastructure. For example, as one interviewee highlights, Mississauga's Downtown21 plan, is structured around increasing employment density through transit-supportive development. However, economic incentives are necessary to offset high costs, as "*developers face challenges like underground parking costs and transit infrastructure*" (Mississauga Interviewee #2). Markham shares similar struggles but has seen progress with initiatives like convincing VIVA to relocate to an office in Markham Centre, a success attributed to proximity to amenities and the pedestrian-friendly environment and large surface parking lots: "*They're literally right across the street from cinemas, restaurants, and daycare*" (Markham Interviewee #4). As another interviewee mentioned "*structured parking lots are cost premiums that make it much harder in terms of competition between office development inside and outside Markham Centre*" (Markham Interviewee #1)

Transit as a Catalyst for Development

The topic of transit was frequently brought up during the interviews as a key intervention in the transformation of both Mississauga and Markham into intensified urban centers. In Mississauga, the introduction of the Light Rail Transit (LRT) along the Hurontario corridor represents a shift towards high-order transit. As one interviewee stated, "*The LRT is going to add to the mobility of people... a game changer for the downtown*" (Mississauga Interviewee #3). Similarly, the City of Markham leverages the Viva Rapidway and the proposed Highway 407 Transitway to transform the Markham Centre as a regional hub. Moreover, interviewees from both case studies mentioned interventions to improve reliability and convenience of the local transit services. For instance, one Mississauga interviewee mentioned: "*instead of these direct sprinkle routs and the zig-zaggy scheme, we want to have straight routes as much as possible. And with that we look at the City Centre and our terminal there*" (Mississauga Interviewee #3). The emphasis on transit aligns with creating mixed-use, pedestrian-friendly environments, which, as noted, will "*tie together regional transit and local urban services, making the downtown more accessible*" (Markham Interviewee #1). These transit projects aim to enhance connectivity and reduce car dependent commuting, which was a key theme in all interviews.

Pedestrian Environments and Walkability

Both cities highlight the importance of creating pedestrian-friendly urban spaces, which is linked to transit and sustainability initiatives. In Mississauga, the Downtown21 plan emphasizes improved walkability, recognizing that "*all transit starts and ends as a pedestrian trip. So, the more walkable, the more pleasing we can make it*" (Mississauga Interviewee #5). In Downtown Mississauga, the design of Celebration Square and the surrounding areas aims to create vibrant pedestrian corridors, though the lack of connectivity between some districts is acknowledged as a challenge (Mississauga Interviewee #1). Markham's pedestrian environments are similarly a work in progress. As noted by one interviewee, "*We're making wider sidewalks, requiring buildings to come closer to the street, and creating pedestrian-friendly streetscapes*" (Markham Interviewee #2). However, the fragmented nature of developments has resulted in limited pedestrian connections. "*Markham Centre has 20 years of building ahead... it will take time before we achieve a completed network of streets, sidewalks, and bike lanes*" (Markham Interviewee #1).

The integration of pedestrian pathways with green infrastructure is another point of focus in Markham, where trail systems through the Rouge Valley aim to enhance walkability while preserving natural heritage. As one interviewee explained, "*The trails provide accessibility for walking and biking, though they are limited by narrow buffers and dense development*" (Markham Interviewee #5). These efforts underscore the cities' commitment to enabling active transportation as a key strategy for urban mobility.

Urban Growth and Sustainability Challenges

The challenges of intensification in terms of transit integration and environmental preservation were highlighted in the interviews. For Downtown Mississauga, highways and the Credit River were identified as "barriers in terms of continuity of services," *complicating efforts to create connected pedestrian and transit networks* (Mississauga Interviewee #5). Markham Centre, however, faces the impacts of dense urbanization on natural heritage features, especially the Rouge Valley. Interviewees noted that "*development pressures always impact the size of woodlands, although these areas are largely protected under local policies*" (Markham Interviewee #2). Despite these constraints, both cities have integrated sustainability into their development frameworks, with one interviewee emphasizing that "*all new developments in Markham Centre must align with LEED standards and green building practices*" (Markham Interviewee #4).

Community and Stakeholder Collaboration

A recurring theme was the critical role of community engagement. In Mississauga, stakeholders from various departments ensure alignment across parks, streetscapes, and transit planning (Mississauga Interviewee #5). Markham takes a more structured approach through its advisory committees, which actively involve residents and developers in decision-making. One participant explained, "T*he Markham Centre Advisory focuses on key themes like transportation, green infrastructure, and public spaces... making it a collaborative effort*" (Markham Interviewee #1). This participatory approach ensures that urban development aligns with community expectations while fostering inclusivity.

Institutional Barriers

In both case studies, institutional barriers in terms of fragmented governance and inter-agency coordination issues were frequently cited as obstacles to the realization of urban planning objectives. In Mississauga, overlapping responsibilities between federal, provincial, and municipal bodies were mentioned as a challenge particularly in projects like the LRT. One interviewee noted, "*Transitway is a joint project between the federal, provincial, and municipal governments, but aligning our priorities is difficult*" (Mississauga Interviewee #3). Similarly, the lack of communication between transit agencies such as GO Transit and MiWay made the joint efforts to plan and integrate transit services challenging (Mississauga Interviewee #5). Markham faces its own unique institutional constraints, particularly in managing its advisory committees and development frameworks. While the Markham Centre Advisory provides a platform for stakeholders, its decisions are limited by the overarching mandates of provincial and regional planning bodies. As one interviewee explained, "*The UGC designation came from the province, and we had to align our plans within that framework, sometimes at the expense of local priorities*" (Markham Interviewee #4).

Challenges in Implementing the Plans

Despite ambitious visions, the interviewees pointed out the challenges in implementation of urban planning initiatives, including financial constraints, public opposition, as well as unforeseen logistical constraints. In Downtown Mississauga, the cost of infrastructure upgrades, particularly related to transit, was a recurring challenge. As one participant emphasized, "*We have to replace two lanes of traffic with LRT, but construction will take five years, significantly disrupting the downtown*" (Mississauga Interviewee #3). Additionally, car dependency and the public's reluctance to embrace transit remain persistent obstacles: "*People love their cars, and with all the traffic projections, it's difficult to achieve the needed modal shift*" (Mississauga Interviewee #5). On the other hand, Markham Centre's challenges include balancing rapid urbanization with environmental preservation. One interviewee pointed out, "*The Rouge Valley's edges are under stress from road crossings and urban encroachment. It makes it really*

difficult to maintain ecological integrity while accommodating growth" (Markham Interviewee #5). The high cost of parking infrastructure further complicates efforts to attract businesses and residents to the urban core. "*Developers face challenges like underground parking costs... it's hard to compete with cheaper options in other parts of the GTA*" (Markham Interviewee #1). Moreover, public consultations often delayed implementation timelines. As one interviewee noted, "*Engaging residents is critical, but it takes months to address concerns and incorporate feedback into project designs*" (Markham Interviewee #2).

Although the provided synthesis of the interviews' findings provides a general picture of the challenges of intensifying the UGCs, these results need to be attested against other resources to understand the underlying causes that prohibit the connectivity of GI and pedestrian networks in the intensification areas, which will be discussed in the reminder of this section.

4.4.2 The Negative Impact of Large-size Urban Blocks on Pedestrian Connectivity

To enable pedestrian-scale connectivity, urban blocks in city centres need to be smaller than typical suburban blocks. Large-size urban blocks reduce the permeability of pedestrian movement in two ways: they increase walking time, and they lack desirable physical characteristics of pedestrian networks. In terms of walking duration, the comfortable duration for pedestrian is 5 to 10 minutes (Radall & Beatz, 2001). Therefore, preferable urban blocks for walking have a block perimeter of between 400 meter and 650 meters. Moreover, each side of a square block should not be more than 120 to 140 meters.

When one compares the recommended block dimensions to the case studies, it becomes obvious that these developments as currently constituted are not compatible with best practices. In both case studies, the block sides are between 250 meters and up to 2km without any intersections. The examples are the urban blocks along highway 7 in Markham Centre and its perpendicular roads such as Warden Rd and Birchmount Rd as well as urban blocks along Burnhamthorpe Rd in Downtown Mississauga (City of Markham, 2021; City of Mississauga, 2010; Google Earth, 2022).

Large-size urban blocks lack physical characteristics of pedestrian networks since these are associated with long and monotone facades. This degrades the interactive pedestrian experience and reduces the desire to walk (Kirnbauer & Baetz, 2014). In Markham Centre, the sides of original urban blocks can reach beyond 1km of length with limited interaction with pedestrians. For example, Birchmount Rd contains a new crossing over the Rouge Valley, Canada's only designated urban Provincial park. This crossing is shown in Figure 4-2. It is 1 km, takes 13 minutes to walk, and was constructed in 2014 to connect the development on the two sides of the Valley (City of Markham, 2020; Google, 2023). Although there are pedestrian destinations (i.e., a shopping plaza and an entertainment complex) at the

ends of this crossing, this crossing is rarely used by pedestrians due to the lack of engaging pedestrian features, such as view to the Rouge Valley (blocked by fences), entrances to the Rouge Valley, pedestrian-scale frontages, and intersections. An interviewee stated, "We are getting a series of masses in Markham Centre to facilitate walking. They can walk up to the restaurants over there. There are a lot of stores and LCBO. There is a cinema on the other side of the bridge now. But there are still gaps in the fabric." (Markham Interviewee #1; Google 2023).



Figure 4-2 Example of crossings over the Rouge Valley without interactions with the surroundings. Top: highlighting the long walk between two destinations, bottom; pedestrian view over the bridge.

4.4.3 The Negative Impact of Car-dominated Roads on Pedestrian Connectivity

In car-oriented developments, wide, high-volume, high-speed facilities including limited access highways and arterials tend to be the main routes. These designs create major obstacles for the movement of pedestrians. Delso et al. (2019) argue that for pedestrians, high traffic roads with more than 5000 vehicles per hour are 40% less desirable than pedestrian roads and pathways (Delso et al., 2019). Naturally, the impact of auto-dominance on the prevalence of walking varies by population. As an example, due to

safety issues, best practice for pedestrian access to public schools suggest that students should have the ability to arrive at school without traversing an arterial (Radall & Beatz, 2001).

Returning to the case studies, it is clear that these areas are designed and function in ways that promote the automobile, to the detriment of active modes. The presence of high-speed cars reduce pedestrian safety; the air and noise pollution from motorized vehicles negatively influence their experience. The presence of utility lines in the case studies create unsightly physical features alongside the roads, further reducing pedestrian comfort. For example, as one respondent states, if the city had enough funding to bury the power lines and get rid of the poles, Highway 7 would be a significantly improved pedestrian environment (Markham Interviewee #1).

Large, suburban arterials also limit the movements of pedestrians, particularly in trying to cross the arterial. A lack (or absence) of bridges, crosswalks, and mid-block crosswalks as well as the scarcity of pedestrian traffic lights with significant wait time at each one present substantive obstacles for pedestrians. The impacts of these designs are evident in the case studies. For example, one interviewee stated that in Downtown Mississauga, large arterials and Highway 403 isolate the internal blocks of the Centre from surrounding neighbourhoods (Mississauga Interviewee #1). In Markham Centre, the distance between crosswalks over the high-speed arterials and highways can reach up to 500 meters (Google, 2023). The Mildred Temple Park is a block-size park in Markham Centre south of the Highway 7, which is disconnected from a residential development north of the Highway 7 because of the lack of crosswalks (i.e., on Highway 7 and Main St. Unionville on the west- end of the park). Hence, the City has planned to develop an easy mid-block crossing over Highway 7 for the park (Markham Interviewee #1).

4.4.4 The Negative Impact of Large-size Urban Blocks on GI Connectivity

Large-size urban blocks interrupt GI connectivity by obstructing the flow of nutrition (water and air) and the movement of species. These large urban blocks are typically paved, increasing the impermeability of urban surfaces. The lack of soil and vegetation in impervious surfaces of large-size blocks degrades ecosystem functions by eliminating natural processes, such as carbon uptake, water infiltration, and evapotranspiration. Mittermüller et al. (2021) argue that undisturbed (undeveloped) green coverage reduces the surface temperatures (Mittermüller et al., 2021); presumably the alternative is true converting greenspace to developed area results in concentrations of heat, decreasing pedestrian comfort and ecosystem performance.

Traditional designs of large-size urban blocks also result in more difficult active transportation. Larger block sizes decrease intersection density, requiring longer walking distances to cross; moreover, large block areas have not been designed to be “permeable”, with fewer access or entry points to the

development contained within the block. These designs also influence the ecosystem performance. The minimum intersections and openings of building façades in large-size urban blocks reduce the penetration of ecosystem services from parks and green spaces to the surrounding neighbourhoods. For example, the cooling effect inside urban blocks with tree canopies is greater than blocks without trees. However, the increased perimeter of urban blocks reduces the penetration of this cooling effect to their surrounding areas (Jack Ahern et al., 2014; Penone et al., 2012; Yafei Wang et al., 2014).

One of the main urban spaces associated with large-size urban blocks is surface parking area, which includes expansive, impervious surfaces. Surface parking areas are single-purpose allocations of land, which are a dominant land use in car–oriented developments. Although pedestrians and cyclists walk across surface parking areas, these spaces are still undesirable and unsafe for these users because of their unregulated and expansive spaces, the presence of cars, and the lack of pedestrian activities and frontages (Schwarz, 2012). Meanwhile, surface parking areas traditionally replace vegetation with impervious surfaces leading to eradication of ecosystems and are considered as a major source of urban runoff. (Tsegaye et al., 2019). The presence of surface parking is certainly a negative attribute in the case studies areas. One of the interviewees specifically identified that in Downtown Mississauga, "large parking lots produce exponentially larger runoff volumes compared to street parking spaces" (Mississauga Interviewee #2).

4.4.5 The Negative Impact of Car-dominated Roads on the GI Connectivity

When roads are configured as wide, contiguous, impermeable spaces, they tend to negatively impact GI connectivity as barriers in natural ecosystems. These roads scatter and isolate GI habitat patches, such as creeks, parks, undeveloped lands, and natural areas. Hence, they disturb the flow and exchange of nutrients, such as water infiltration and airflow as well as the movement of species, such as birds, bees, and butterflies. For example, butterflies can fly between trees on opposite sides of a narrow road, but they cannot cross arterials (Lynch, 2019). This leads to environmental issues, such as increased pollutants, road salt from high volume car traffic, creek erosion, the absence of species migration and the reduction of pollinators and pollens exchange between green spaces (City of Markham, 2021; Green Roofs for Healthy Cities, 2015; Lynch, 2019; Penone et al., 2012).

This dissertation argues for blending GI and intensification in contemporary designs aimed at achieving sustainability through intensification. Further, the dissertation identifies pedestrian facilities that share the desired attribute of connectivity, as priority areas for GI within the built environment of intensification. This section has presented an overview of typical built environment barriers to co-developing GI and pedestrian connectivity. The comparative case studies show that large-size urban

blocks and car-dominated roads are the primary barriers to developing GI and pedestrian connectivity. In Downtown Mississauga, the parks are mostly located around the circumference of the centre while in Markham Centre, the Rouge River crosses the centre. In Downtown Mississauga, pedestrian routes are continuous while in Markham Centre pedestrian routes are fragmented by the Rouge Valley and development patches.

To overcome these barriers, this research focuses designers' attention to Urban Parks and Open Spaces as the shared space in which co-development of GI and pedestrian connectivity should be prioritized. The following section investigates this design approach in both case studies to understand where the enhancement of GI and pedestrian connectivity can co-occur.

4.5 Providing GI and Pedestrian Connectivity on an Urban Scale in the Case Studies

In Urban Growth Centres, as identified in the case studies, designs often create large-size blocks and along car-dominated roads. As such, in both case studies, I suggest modifications from car-dominated roads to multifunctional links, while breaking down large-size urban blocks to smaller and mixed-use blocks. The outcomes of these changes allow for the introduction of significant, impactful GI along corridors that simultaneously greatly enhance pedestrian connectivity.

The penetration of GI measures and pedestrian activities within the built environment of UGCs can be accomplished by strategies such as developing parks, designing new street grids, daylighting creeks, and repurposing existing spaces, including vacant lands and surface parking areas. These strategies are planned and implemented in different UPOSs, such as parks and roads (City of Markham, 2020; City of Mississauga, 2010, 2013). In the following section, the current provision of GI and pedestrian connectivity in the case studies is classified based on different UPOSs.

4.5.1 Current Provision of GI Connectivity on an Urban Scale

Natural Corridors

Natural corridors (NCs) in cities, such as preservation areas and parks can mimic natural processes and serve as the main habitat patches of GI networks in urban areas, which play a key role in providing ecosystem services for urban dwellers. However, protected conservation areas, where pedestrians have no access, are excluded in this study because those areas do not contribute to pedestrian connectivity. In the plans of both case study municipalities, most interventions for GI elements are intended for parks and areas around creeks (City of Markham, 2020; City of Mississauga, 2010, 2013).

Parks

In areas under intensification, instead of large parks commonly found in suburban areas, high-quality parks in a variety of sizes are developed from a suburban large-block size to a single-property size. These parks provide ecological functions through intensive greenspaces, selected plant species, and designed landscaping. Importantly, they can contribute to GI connectivity since these are scattered in centres and can be connected through GI corridors, such as tree-lines streets, creek corridors, and trails. At the same time, these are accessible to pedestrians and provide community activities all over centres (Breuste & Artmann, 2020; City of Mississauga, 2010).

Both Markham Centre and Downtown Mississauga plan to develop a variety of multi-size parks. The city of Mississauga is working to develop large parks in the outer ring of the centre as well as scattered parks within the centre (City of Mississauga, 2010). The location of the parks in Downtown Mississauga are shown in Figure 4-3. In Markham Centre, there is a central natural heritage system (i.e. the Rouge Valley), which passes through the centre and is accompanied with small public parks in its buffer zone (the required width between development and the Rouge Valley). To create more opportunities for passive and active recreation, the City plans to expand buffer zones to serve as public parks. These spaces have a minimum width of 10 m, and are connected to other urban green spaces of the centre, such as public plazas and schools. The distribution of green spaces in Markham Centre is illustrated in Figure 4-4. The green spaces in Markham Centre are expected to host various pedestrian activities. For example, a new north-south utility corridor is anticipated to accommodate outdoor sports and active recreation (Markham Interviewee #3).



Figure 4-3 distribution of parks around the outer ring of Downtown Mississauga.



Figure 4-4 Location of parks, buffer zone (edge parks), and other green spaces in Markham Centre (City of Markham)

Creeks

Creeks are essential parts of GI networks, dealing with the discharge of storm drains, receiving and infiltrate surface waters, while providing other ecosystem services such as wildlife habitat provision and climate regulation (Firehock & Walker, 2015; Lynch, 2019). To improve the overall connectivity of creeks, the city of Mississauga has proposed number of restoration interventions. This includes the daylighting of the piped section of Mary Fix creek, as well as the development of a new 1-hectare wetland in Rathburn, a linear park / trail alongside the Cooksville Creek, and a new greenway along Mary Fix creek. The locations of these interventions are highlighted in Figure 4-3 (City of Mississauga, 2010; Google, 2023; Green Infrastructure Foundation, 2018; Green Roofs for Healthy Cities, 2015).

In Markham Centre, possible design modifications are influenced by the core objective of protecting the Rouge River. To improve the connectivity of Rouge, the City of Markham is considering the rehabilitation of some stormwater management ponds. For example, as part of the transformation of the Unionville GO Station, alternatives for a large stormwater treatment facility, including stream daylighting and open channel designs have been proposed (City of Markham, 2020; Hanchard, 2021).

Roads

Although roads are the major cause of fragmentation of GI networks due to their continuation, width, and impervious surface, they can include critical areas of defragmentation, such as permeable infrastructure

for wildlife and nutrients (e.g. tree canopies, street trees, roadside vegetation) and engineered structures (e.g. bioswales, retention ponds, living wall). For GI connectivity, developing street trees and vegetation along roads are the main interventions.

In Downtown Mississauga, the Downtown21 plan proposes augmenting all roads with street trees and developing bioswales in Centre View Drive to assist in creating green corridors. The plan also proposes different spacing between trees for different types of roads. For Markham Centre, the expansion of vegetation cover and tree canopy are likewise promoted (City of Markham, 2020).

Surface Parking Areas

Surface parking areas in suburbs are often substantive interruptions to GI connectivity and are considered as a major source of urban runoff, because of their impervious surfaces and the lack of vegetation (Tsegaye et al., 2019). In contemporary design thinking, these surface areas are now conceived as opportunities for infill development and redevelopment as well as green space development during the intensification process (Zagorskas, 2016). Such proposals are being contemplated in the case study areas. As an example, one of the IBM surface parking areas in Markham Centre is planned to be replaced by a 16-hectare park (City of Markham, 2021).

Beyond repurposing parking areas, opportunities exist to maintain the levels of parking, but to decrease the disruptive effects. In both case studies, some surface parking areas over time are proposed to be replaced with structured / belowground parking facilities. Often, surface-parking conversions will be coupled with Low-Impact Design (LID) measures to reduce their runoff. However, LID measures are rarely implemented in both case studies. In Markham Centre, since LID measures are required in surface parking areas, there are a few implementation examples (Markham Interviewee #5; City of Markham, 2021).

Private Lands that are Integrated with UPOSs

In both case studies, integrating private green areas with public ones is planned to enhance GI connectivity. The city of Mississauga plans to augment the multi-size public parks of the downtown with GI on private lands. A good example is on east of the centre, where trees and vegetation in residential properties are connected with the surrounding Mississauga Valley Park (Mississauga Interviewee #3, Downtown21).

In Markham Centre, there are similar efforts to enhance a public interface with the Rouge Valley through integrating private green spaces. The city negotiated with the owners of private properties that back onto the Rouge Valley to “make sure there is always a direct public interface with the valley” (Markham

Interviewee #2). As another example, for GI connectivity in Markham Centre, a water chamber (marked as "Tributary 5" in Figure 4-4) purchased from a private owner that was made public, and then re-naturalized in collaboration with the Toronto and Region Conservation Authority (TRCA) to increase GI connectivity with surrounding natural habitat. An interviewee respondent highlighted this project: "… has been very successful in terms of connectivity, restoration, and regeneration. There is now wildlife in there, turtles and a variety of birds, snakes and a whole lot of things. So, it has been successful in terms of how it has been taken over by nature." (Markham Interviewee #2). The buffer zone is highlighted as "Greenway Edge Parks" in Figure 4-4.

4.5.2 Current Provision of Pedestrian Connectivity on an Urban Scale

The case studies present| three primary opportunities for enhancing pedestrian connectivity. These include increasing street connectivity (density), developing and enhancing pedestrian routes and creating vibrant urban environments. Adding street intersection can reduce block sizes and create an improved pedestrian environment alongside car-dominated roads. Improving pedestrian routes can connect urban blocks and facilitate pedestrian movement adjacent to car-dominated roads and alternative paths (non-sidewalk pedestrian paths). Creating a vibrant urban environment can contribute to making block sizes with human scale and creating interactive pedestrian experiences. These strategies are proposed and implemented in the following UPOSs.

Roads

Both case studies try to transform car-dominated roads to pedestrian-friendly environments by three types of interventions. Firstly, the street connectivity of roads as the indicator of pedestrian connectivity can be enhanced. This is accomplished by strategies, such as adding mid-block roads and pedestrian pathways (i.e., introducing new roads and pathways in middle of large blocks to reduce the size of the blocks), increasing the number of crosswalks (e.g., introducing crosswalks in between intersections), widening sidewalks, and reducing traffic speed. Downtown Mississauga is intended to refine its suburban super-blocks by strategically introducing new streets. The proposed street grid includes 400-meter circumference blocks with new mid-block roads in north-south roads (e.g. Living Arts Drive and Centre View Drive Road extensions) and east-west roads (e.g. adding a northern distribution road to the north of Highway 403, and extensions of Webb Drive and Princes Royal Drive).

Similarly, Markham Centre is trying to increase the number of road crossings over the Rouge River while carefully analysing their impacts on the Rouge River ecosystem through environmental assessments. Markham Centre is significantly larger than Downtown Mississauga and the protected Rouge Valley area,

arterial roads, and railroads together create six distinctive districts with few road connections. For example, the two districts north of Highway 407 are connected by one road of Enterprise Boulevard. The city is planning to add 6 more crossings to the 10 existing ones. At the same time, the street network is modified to be more direct (e.g. at Yorktech-Enterprise connection) and regular (e.g. at the new transit hub around the existing GO station) (City of Markham, 2021; Google, 2023). The proposed street network by the masterplans for the case studies are shown in Figure 4-5.

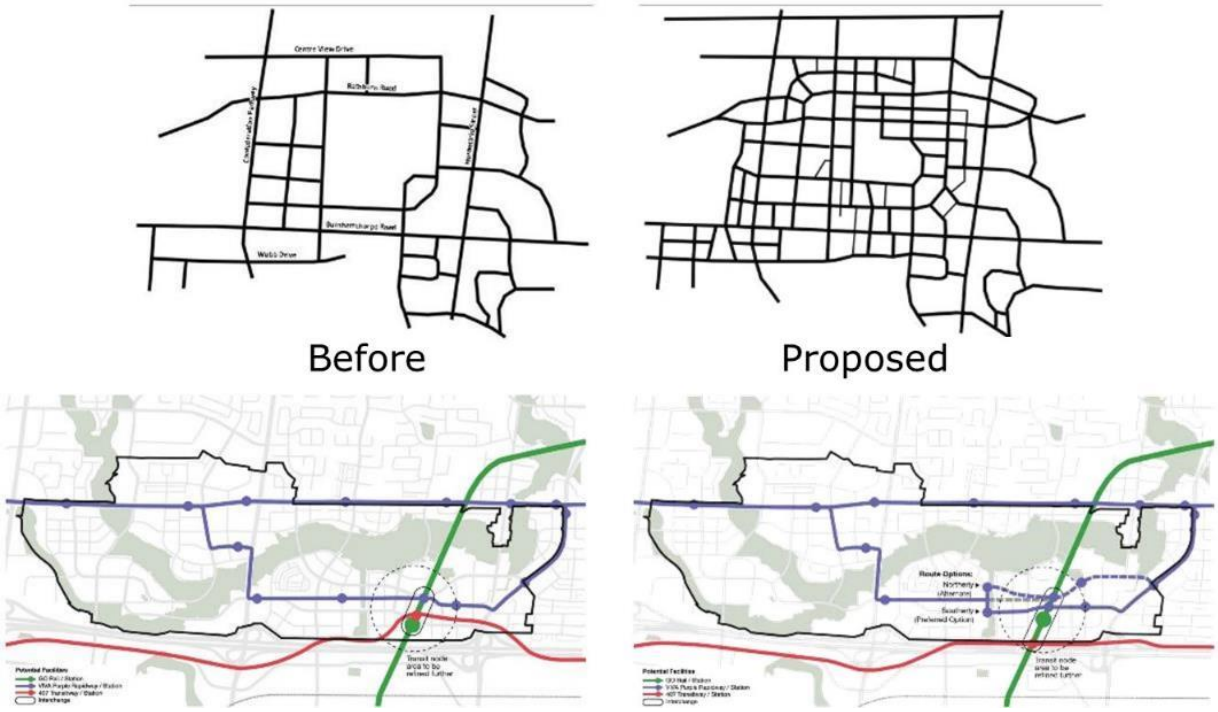


Figure 4-5 Street Networks proposed by the current masterplans for Downtown Mississauga 9top) and Markham Centre (Bottom) (City of Mississauga; City of Markham)

Additionally, roads can be improved for pedestrians by containing GI features, such as new neighborhood parks, pocket parks, street trees, and green spaces as well as public realm features, such as pathways between buildings, urban plazas and street art. These features are planned to be integrated with new small blocks and to connect new small blocks with existing larger parks and civic spaces. For example, Mississauga's Confederation Square is proposed to connect Zonta Meadows Park with the Community Common and the Living Arts Park to the west of the downtown. One interviewee describes: *"canopies, long sidewalks, pedestrian scale lighting, street trees … in narrower street sections that feel more comfortable and begin to slow down the traffic"* (Mississauga Interviewee #3). This approach also addresses the lack of public access to green spaces in areas under intensification as one respondent mentioned: "*Everybody used to live in houses with a baseball field in the back. Now we have people*

living in the sky[scrapers] and the needs are different. So hopefully our goal is to get large-size parks, medium size, and tiny ones with some private spaces that are publicly accessible" (Mississauga Interviewee #3). The street grid and the location of GI elements in Downtown Mississauga is shown in Figure 4-6.

At the same time, the city of Markham allows individual developers to suggest their own walking environments, such as pathways between buildings and parkettes. Then, the city applies minor changes to the road network. However, the connectivity between these clusters is missing. As one respondent states, *"Part of the problem is not one continuous project. We have Rimington doing something down here, Times doing something here. We have other landowners scattered around the downtown. It is a bit of a challenge to connect the dots. That may happen over time. It's not happening now"* (Markham Interviewee #1).



Figure 4-6 Street grid and GI elements in Mississauga (City of Mississauga).

Thirdly, activating street frontages is a significant strategy for increasing pedestrian connectivity along roads because it promotes a vibrant environment for pedestrians. To achieve this goal, Mississauga requires that the entire area of the downtown must be no more than 5 minutes walking distance from active frontages. The city also mandates that all the frontages of parks, plazas, and streets on the north,

east and south side of the Square One shopping mall must have retail/residential activity. In Markham Centre, the streets around the proposed nine plazas in its six districts are required to have activated frontages. As Markham Centre occupies a significantly larger area than that of Downtown Mississauga, 15-minute walking distances in its six districts is the goal for improving the pedestrian environment (Google, 2023; Markham Interviewee #3; Mississauga Interviewee #1, City of Markham, 2021). The walking distances in the two case study UGCs are shown in Figure 4-7.

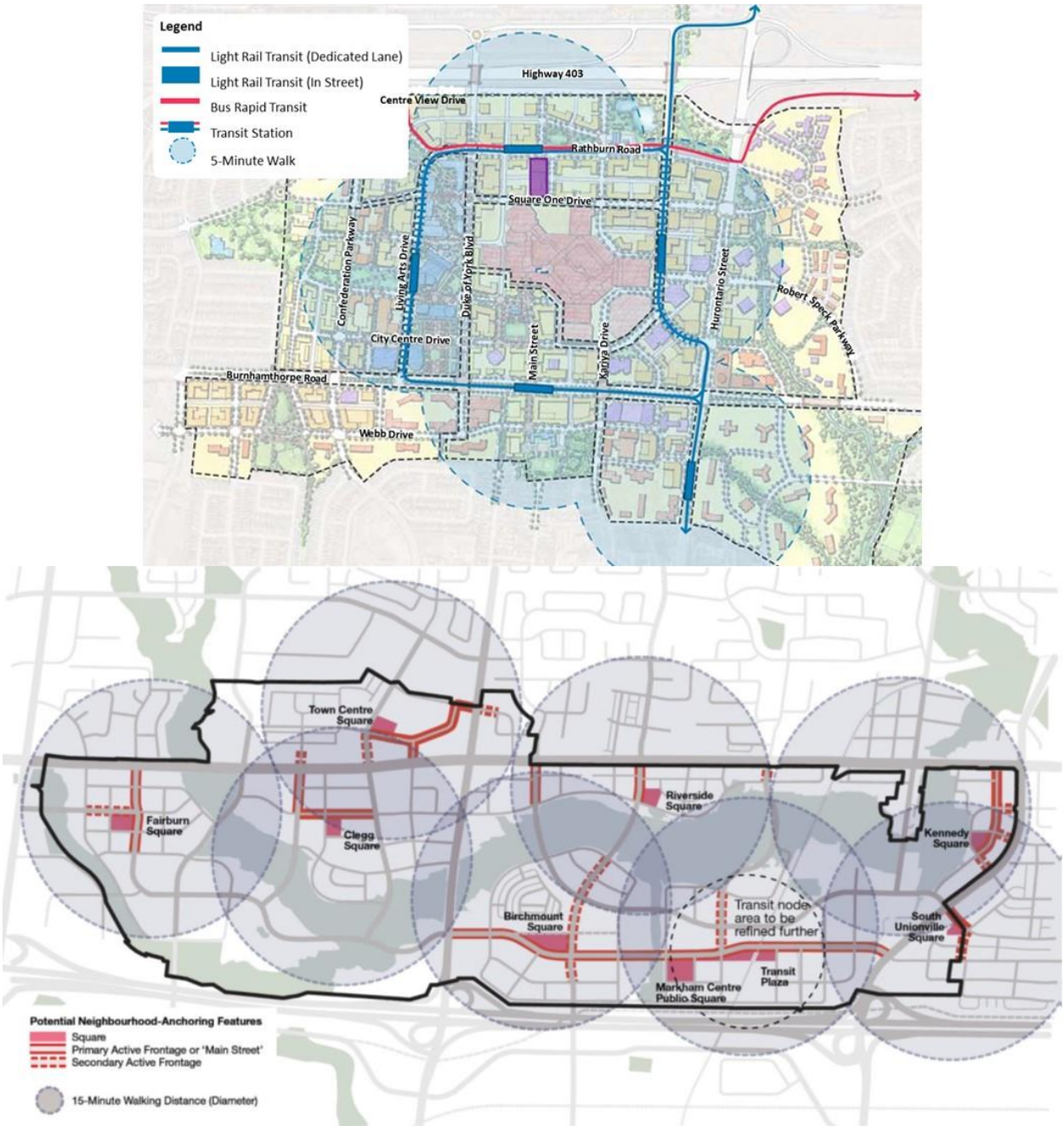


Figure 4-7 Comparing 5- and 15- minutes walking distances in Mississauga and Markham Centres, respectively (City of Markham, 2020; City of Mississauga, 2010).

Surface Parking Areas

The transformation of surface parking areas can enhance pedestrian connectivity. As the surface parking areas of both centres are planned for infill and new development, opportunities exist in the green space development and the interventions that can address pedestrian connectivity. Currently, although pedestrians and cyclists use surface parking areas to get to their destinations and automobiles, these spaces are undesirable and unsafe to walk because of their unregulated and expansive spaces, the presence of cars, and the lack of pedestrian activities and frontages (Schwarz, 2012). For the transformation of surface parking areas, Downtown Mississauga proposes the breakdown of these to small blocks while Markham Centre permits new developments in surface parking areas while requiring developers compensate for these parking areas by building structured parking. However, due to high water table in Markham Centre, underground parking is not encouraged yet (Markham Interviewee #3).

As the number of local employment opportunities increase in Markham Centre, the need for automobile transportation and surface parking areas is expected to decline. This is because higher employment numbers lead to improved public transit support, housing developments near workplaces, and convenient commuting options, such as walking or using public transit. Consequently, people would have convenient alternatives to private cars. Hence, the city has planned to replace the employment related surface parking areas by aboveground parking structures and mixed-use developments. One respondent mentions "*we are still looking to reduce those parking standards to further the idea that we are creating pedestrian environments*" (Markham Interviewee #2; #4; Han et al., 2020). One example is the infill development plan of the area near Unionville GO station in Markham Centre to create a mobility hub in this district. This plan proposes replacing the surface parking area in the vicinity of the GO station with mixed-use developments, including a civic centre. Pedestrian features of this plan include new road crossings, trail crossings, and the modified street network with a dense and regular grid, which provide access to the mixed-use developments (City of Markham, 2021; 2020; Markham Interviewee #5).

Natural Corridors

Both case studies have plans for developing trail networks in their NCs. Downtown Mississauga has developed two multi-use trail networks along its creeks. One is along the Cooksville Creek to the east of the centre, and the other is along the Mary Fix Creek to the west. In addition, there are some proposed trail networks along Downtown Mississauga roads, such as Burnhamthorpe Rd and the City Centre Drive (City of Mississauga, 2010).

In Markham Centre, although the Rouge Valley is seen as a barrier for improving street connectivity, efforts are underway to make active transportation the dominant mode of transportation by focusing on pedestrian connectivity for connecting different districts of the centre. Accordingly, recent plans add 10 trail crossings across the valley as well as a handful of continuous trails alongside the buffer zones for active transportation, which are then linked to neighbouring districts (City of Markham, 2020, 2021).

Overall, Markham Centre is less pedestrian-friendly than Downtown Mississauga, as the development of Markham Centre began in 1994 with limited prior development. Moreover, the population and amount of development in Markham Centre has not reached a level that these solutions are effective. As one respondent puts it: "*Unfortunately there is just a critical mass in terms of population to support that practice* (of mixed use). *We have the opportunity whether its retail uses, whether its amenity uses, whether it's encouraging residential uses in a very close relationship to the street... but it takes time*" (Markham Interviewee #1).

This section compared the provision of GI and pedestrian connectivity in both case studies to answer one of the main research questions of this dissertation: where the integration of GI and pedestrian connectivity can happen in areas under intensification. While the UPOSs that provide GI and pedestrian connectivity are different in the two case studies, in both case studies, for each GI intervention, there is a counterpart pedestrian intervention in the same UPOSs. For example, in Downtown Mississauga, street trees are added to the sidewalks of the major roads for increasing GI connectivity while the same sidewalks are widened for improving pedestrian connectivity. Meanwhile, in Markham Centre, crossings over the Rouge Valley maintain both GI elements and pedestrian trails. The following section categorizes the above-mentioned UPOSs as proper spaces for integrating GI and pedestrian connectivity and tries to understand implementation gaps of case study municipalities for developing GI and pedestrian connectivity in each UPOSs.

4.6 Finding Space for Blending GI Connectivity and Pedestrian Connectivity in Intensified Urban Areas

As the plans and interviews of case studies show, specific types of UPOSs are targeted for developing GI and pedestrian connectivity. This provides spatial opportunities for developing GI steppingstones, such as a discrete set of managed "verge" areas covered with trees and vegetation while designing safety and age-appropriate features for pedestrians, such as various play equipment, designed trails for walking and cycling, urban furniture, and lightings (Canada, 2014; City of Mississauga, 2010; Veitch et al., 2013). In both case studies, all the GI and pedestrian interventions are located in either publicly owned urban areas

that are not occupied by residential/commercial buildings (parks, plazas, roads, parking lots, etc.) or underutilized lands where local governments shape the future of the centres through development proposals (greenfield and brownfields). However, there are currently no design guidelines for providing space for GI and pedestrian networks within large-size urban blocks and car oriented roads of the case studies. The following section seeks to provide evidence suggesting that integration is taking place in the identified UPOSs.

This section explores the UPOSs where the interventions for GI and pedestrian networks can be implemented at the same time. The potential UPOSs for integrating GI and pedestrian connectivity are categorized in four reoccurring types of spaces: Arterial Roads and Highways (ARHs), Collector and Local Roads (CLRs), Underutilized and Surface Parking Lots (USPLs), and Natural Corridors (NCs). Table 4-1 includes the definition, current plans, and interventions of GI and pedestrian connectivity in each category.

Table 4-1 Description of the Categories of UPOSs.

	Arterial Roads and Highways (ARHs)	Collector and Local Roads (CLRs)	Natural Corridors (NCs)	Underutilized and Surface Parking Lots (USPLs)
Function and accessibility	• Roads with 3+ car lanes, • Traffic movement as main function, • Set boundaries of Centre, • Limited to no access to properties	• Roads with up to 3 car lanes, • Property access as the main function, • Traffic movement to a lesser extent than ARHs	• Parks and natural features such as creeks • Habitat Patches for GI • Urban heat island reduction	• Single purpose parking or other • %40 area of the centres, • No access to properties • Development priority for intensification,
Active transportation situation	• Issues due to traffic volume and speed, • Limited pedestrian access, • Unprotected sidewalks, • No destination for pedestrian, • Urban discconnectivity	• Accessible to pedestrians by sidewalks, • Hosts a majority of recreational walking	• Accessible to pedestrians through trails or restricted access, • Can disconnect development patches if restricted access	• Limited pedestrian access, • Not designed to conduct the movement of pedestrians
Current Active Transportation Interventions	• Transforming into compact and multifunctional streets	• Replacing some car lanes with active transportation • Sidewalks flush with buildings	• Trail plans	• Mississauga- transforming to mix-use development in small lots • Markham- temporary lots to be replaced
Potential Active Transportation Interventions	• Inclusion of destinations, • Lane reductions, • Separation from sidewalks, • Widening sidewalks, • Street furniture, • Transforming sidewalks into arterial trails (Xu, 2017).	• Expanding sidewalks, path, parks and off-road routes, • More appealing environment, • Separating sidewalks and bike lanes	• Multilevel trails	• The inclusion of pathways in public greenfields, • Increase visibility of GI
Pedestrian Connectivity Benefit Potential	• Increasing active transportation access to local roads	• Reduced car dependency • Pedestrian oriented street design	• Enhanced cultural ecosystem services	• Enhance active transportation with pathways • Allowed access to developed greenfield and brownfield destinations
GI Situation	• Overall lack of consistent GI, • Impervious surface cover, • Lack of shade • Lack of Vegetation	• Mostly impervious surface, • Limited green spaces or vegetation in street verges	• Modified land forms(creek channelization), • Disconnection from intensified areas, • Low capacity to cope with climate extremes, • Few educational/recreational ecosystem services	• GI is rarely present in lots, • Underutilized lands have significant potential to contribute to biodiversity
Current GI interventions	• Includes green spaces and street trees but missing clear description and detail for design	• Add vegetation and trees in the centre of roads but • Lacks clear description about the quantity and quality of the vegetation	• Restoration in few sites, • Grant access to natural heritage, • Retrofit urban areas, • Creeks as ecological corridors, • Lack of guidelines,	• City of Toronto requires 30% shading for parking lots
Potential GI Interventions	• Large scale interventions • Tackle root cause of environmental problems such as pollution and noise.	• Omni-directional ecosystem services provision	• Rehabilitating ecosystem services by restoration of modified natural features	• habitat provision, ruderal species (G. Kim et al., 2015; Mathey et al., 2015), • Low cost interventions, • Environmental experiments
GI Connectivity Benefit Potential	• Various regulating ecosystem services	• Connecting public GI with GI in private properties	• Providing connectivity through corridors	• Connecting to GI corridors.
Blending GI and Active Transportation opportunity	• Increasing the internal connectivity traffic safety.		• Balancing the protection strategies and pedestrian access through trail design	

4.6.1 Arterial Roads and Highways (ARHs)

ARHs refer to linear and impervious urban areas with more than three car lanes in total, which are dedicated for high-speed and high-volume car traffic. ARHs are often used for long travel distances and commuting and have minimal access to neighbouring properties (Tsigdinos & Vlastos, 2020). In Downtown Mississauga, ARHs are located on the outer circumference of the centre. Transportation of goods is one of the main local industries, which imposes political pressure to maintain the truck capacity and speed limit of roads. Moreover, there are few and distant traffic lights, which significantly reduces the accessibility of the downtown area to pedestrians and transit users (Mississauga Interviewee #3, #4). Sidewalks along ARHs in Downtown Mississauga are narrow and mostly flanked with street and surface parking areas. In some instances, these are separated by grass as street verges. In many instances, the lack of a barrier between sidewalks mean that the sidewalk is sandwiched between the road and surface parking without any buffers. This proximity to the speed and volume of car traffic creates an unpleasant and unsafe environment for pedestrians.

In Markham Centre, ARHs cut through the centre and divide it into isolated neighborhoods. Within Markham Centre, ARHs are considered the best potential space for developing transit- and pedestrian friendly environments. The city is actively increasing the number of traffic lights and mid-block crosswalks in the centre. Moreover, City urban designers try to provide transit lanes (VIVA Rapid Rail) with transit stations to make these functional for pedestrians and transit users. For GI, the plans for street trees along ARHs are not implemented yet. ARHs include minimal roadside grass turf with scattered trees, which have limited capability to act as stepping stones for GI connectivity and to deal with the urban runoff (Markham Interviewee #1). Importantly, the generally sporadic and monotonous vegetation in ARHs cannot act as barriers between pedestrians and these roads.

Highway 7, in Markham Centre, is the best existing case study example of GI and pedestrian interventions because it is transforming into a multi-purpose road with transit routes, bicycle lanes, and pedestrian sidewalks. A range of GI and pedestrian interventions beside each other are planned there. Examples are widening sidewalks, integrating amenities and storefronts with streets as well as including street planters, street trees and benches in three major intersections with mid-block traffic lights and crosswalks. The sidewalks along highway 7 are separated from the road by street boulevard vegetation in the form of small street trees, flowers, and small shrubs in raised planters.

In both case studies, for pedestrian connectivity, aside from some residential entrances, there is a lack of active frontages for pedestrians in ARHs. In addition, long walking distances along high traffic roads, which are surrounded by surface parking areas do not facilitate pedestrian movements and the available

street verge space does not provide pedestrian features to act as barriers between pedestrians and these roads. For GI connectivity, the generally sporadic and monotonous vegetation in ARHs (aside from the Highway 7 example) does not provide ecosystem services such as water infiltration and erosion control to deal with the runoff from ARHs (City of Mississauga, 2019).

4.6.2 Collectors and Local Roads (CLRs)

CLRs include roads with lower car traffic than ARHs, which provide access to individual properties, rather than transit across larger regions. In contrast with those of ARHs, GI and pedestrian networks of CLRs are not linear and continuous since these are disrupted by driveway entrances. The newly proposed roads in both case studies fall under the category of CLRs. For example, the new street grid of Downtown Mississauga introduces new CLRs with three lanes or less, which not only reduce the automobile traffic load of ARHs by providing more short-route options but also are suitable for pedestrians and bikes. To make CLRs usable for pedestrians, design strategies are implemented, such as reducing the size of urban blocks, adding traffic calming measures, developing the physical features for pedestrians, and creating green spaces. In addition, to activate the frontage of the CLRs, commercial buildings, retails, and plazas are proposed in both case studies the proposed activated frontages are highlighted Figure 4-7 and Figure 4-8.



Figure 4-8 activating frontages in Downtown Mississauga (City of Mississauga, 2010)

However, the potential of green spaces, such as linear parks in creating pedestrian environments along CLRs has only been implemented to a limited degree in both case studies. Although the practice of green streets and the incorporation of LID measures in CLRs are seen in many north American cities (Cain et al., 2014; Thiagarajan et al., 2018), these interventions are only seen outside the two downtown areas examined here. For example, the City of Markham is conducting a green road pilot project, which

incorporates LID components in roads and public plazas in consultation with a local landscape architectural firm that has experience with developing GI on private properties (Markham, 2018). (Markham Interviewee #5; Schollen & Company Inc., 2022).

Recent CLR interventions, which were introduced during the south expansion of the Square One Mall in Downtown Mississauga, are seen along Princess Royal Drive. The entire length of street between the mall and the Confederation Parkway is accompanied by small parks, wide sidewalks, street trees, modular planters, public statues, and pedestrian-oriented facilities such as washrooms and a pet-care facility. However, street verge vegetation is mostly absent from the CLRs throughout the rest of Downtown Mississauga (City of Mississauga, 2010).

In Markham Centre, to facilitate pedestrian permeability throughout CLRs, buildings are planned to be close to streets. Moreover, red lights are being added over the Highway 7 for pedestrian crossings and access to CLRs and parks. With these interventions, the need for parking areas will tend to decline because “people would use the street and walk to the stores instead of taking their cars” (Markham Interviewee #4). Recent CLR interventions in Markham Centre can be found on Town Centre Boulevard, where local shops are fronted by wide sidewalks and transit lanes with three levels of street verge vegetation, which separates different uses of street: pedestrian, vehicular and transit. However, site visits showed that these areas are mulched, which can prohibits the growth of other vegetation, such as weeds and wild grown species, which limits biodiversity (Google, 2023).

4.6.3 Underutilized Lands (ULs)

ULs in the case studies refer to either undeveloped lands or lands that are used in low capacities. This includes vacant lands, brownfields, abandoned industrial sites, surface parking areas, utility corridors, and buffers around railroads. These spaces are anticipated to be transformed through new development, infill development, and retrofit projects. This provides opportunities for developing both GI and pedestrian networks (Mathews et al., 2015; Lokman, 2017) . In both case studies, due to their suburban origins, most ULs are surface parking areas and vacant lands, which are scattered across the centres (City of Markham, 2022a).

Surface Parking Areas

Surface parking areas are a dominant land use in both case studies. In Downtown Mississauga, the massive surface parking areas around the Square One shopping mall are a legacy of the suburban history of the centre. A ring of office development around the Square One shopping mall host a few office buildings, which are still surrounded by another set of surface parking areas. Hence, in Downtown

Mississauga, there are numerous stretches of front facing surface parking areas with no barriers between these and sidewalks (e,g,, south of Burnhamthorpe Ave.). Regarding GI, as these areas are being transformed by infill developments and extensions for the mall, new GI elements are incorporated there. A good example is an approximately 200 meter by 150-meter (2.76 Ha) parking area in the north of the Square One mall, which is divided into 4 blocks with 50–80-meter widths and two new retail buildings, as shown in Figure 4-9. This area includes two internal alleys paved by pervious surfaces, green spaces, and the outer sidewalks separated by small trees and shrubs, shown in Figure 4-10. However, the green spaces of the surface parking areas in Downtown Mississauga are not designed for LID standards and do not provide any pedestrian refuges (City of Mississauga, 2010; Google, 2023).



Figure 4-9 retrofitted surface parking in Downtown Mississauga (Google Earth, 2024)

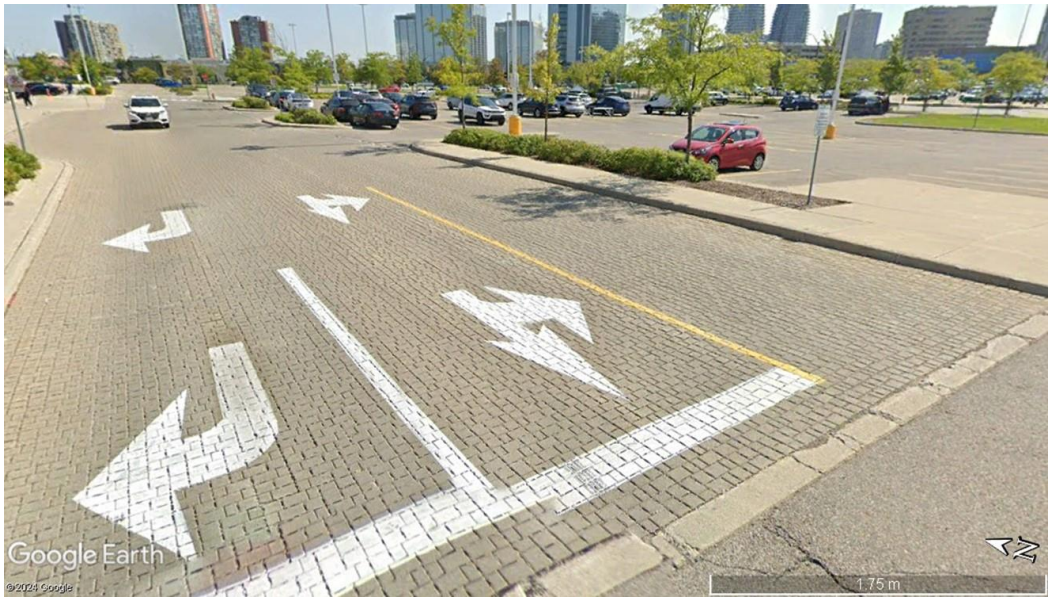


Figure 4-10 pervious alley covered by permeable interlocking tiles

In Markham Centre, surface parking areas have two objectives: supporting commuting and attracting employment. The expansive community parking area near the Unionville GO Station was built to accommodate a traditional commute to Toronto (Markham Interviewee #1). Further, as surface parking areas are temporarily permitted as an incentive to attract employment development, high-rises within or beside large surface parking areas are developed (City of Markham, 2020). Strip malls and auto dealerships, which are characterized by large expanses of surface parking areas also dominate in these areas (Google, 2023).

In terms of GI, temporary surface parking areas in Markham centre are required to address stormwater issues through GI elements. Most surface parking areas do not have curbs and direct stormwater into bioswales. The examples are found throughout Markham Centre, such as bioswales, manmade wetlands, and a rainwater harvesting facility at Bill Crothers Secondary School. Importantly, since surface parking areas are expected to be filled with buildings and structured parking, there is an opportunity to incorporate a wide range of GI elements. For pedestrians, the strategy of Markham Centre for replacing surface parking areas by structured parking areas and using these spaces for pedestrians has not been implemented yet. As one respondent mentions, “we are still looking to reduce those parking standards to further the idea that we are creating pedestrian environments” (Markham Interviewee #2, #3, #4; Han et al., 2020).

One good example of integrating GI and pedestrian connectivity in surface parking areas is in the surface parking areas alongside Highway 7, which are buffered from sidewalks by shrubs and large trees. Using

GI as a barrier to buffer sidewalks has increased the perception of safety and reduced the nuisance of automobile traffic for pedestrians (Google, 2023). One interviewee describes these interventions as "significant landscaping and enhancements" (Markham Interviewee #2).

Both case study municipalities are in the process of phasing out surface parking areas. However, there are only a limited number of interventions that address GI and pedestrian connectivity issues in these spaces. For GI, in Downtown Mississauga, stormwater management measures are missing, and the urban runoff remains a significant issue. Because of Markham Centre's commitment to achieving LEED standards, most surface parking areas in Markham Centre feature GI measures and reduce urban runoff. For pedestrians, in both case studies, the size and the lack of physical features for pedestrians make these areas undesirable environments. However, City officials anticipate that as the centres transform from a car-oriented environment to a transit-friendly area, surface parking areas become available for pedestrians (Mississauga Interviewee #4; Markham Interviewee #4; City of Markham, 2020).

Vacant Lands

Vacant, undeveloped, and derelict lands are urban parcels that are not managed as public spaces and do not contribute to conventional urban land uses (i.e., commercial, residential, retail, recreation, etc.) (Lokman, 2017; Novak, 2019). These lands have limited or no accessibility for pedestrians. In terms of GI, aside from infrequent mowing and pruning of vegetation, no other formal interventions are considered there before development. In areas under intensification, these lands are scarce commodities and are subject to competition for development (Williams, 2004). Unt and Bell, (2014) show that by introducing temporary and inexpensive interventions, such as providing public access to these spaces, removing fences, developing basic trails, and adding removable/modular benches these sites can attract pedestrians as a local leisure destination. Importantly, developing GI elements in these sites can improve the perception of safety and attractiveness for pedestrians (Unt & Bell, 2014).

The area of undeveloped lands in Downtown Mississauga is roughly 20 hectares, which comprises 7% of the total area of the centre. Similarly, the area of undeveloped lands in Markham Centre is about 31 hectares, which is 8% of the total area of Markham Centre (Allan & Campsie, 2013; City of Markham, 2022a; City of Mississauga, 2022). Vacant land areas have been highlighted as opportunities for future development in both centres through design competitions, design charrettes, and internal studies. For example, in Markham Centre, the vacant lands near the Unionville GO station have been the subject of a Mobility Hub study, which included an urban design charrette component with a multi-disciplinary team of stakeholders (Kendall, 2013). Other examples of urban design charrettes for the vacant lands in Markham Centre include the Creative Convergence Hubs Charrette, and the York University new campus

(Institute without Boundaries, 2012; York University, 2022). Similarly, Downtown Mississauga has an example of a vacant land redesign exercise to develop an eco-park with storm ponds connected to bioswales in neighbouring sites, pedestrian-oriented facilities, and a porous pedestrian trail connected to a midblock crossing that leads to additional neighbourhood sidewalks and trails (Green Roofs for Healthy Cities, 2015).

In both case studies, walking along vacant land frontages is undesirable even if there are plentiful destinations within walking distance because these spaces are often fenced to the public and appear less maintained. These are also often covered with wild grown vegetation, which is associated with the perception of reduced safety for pedestrians. As one respondent puts it, *"We have these elements in-place and destinations for people to walk to … but it is a bleak walk partly because of the vacant lands in between. These are gaps in the fabric, and we need some places for people to walk"* (Markham Interviewee #2).

However, vacant lands can significantly contribute to pedestrian connectivity because these areas can contain desire paths (informal paths with traces of walking). Desire paths are not paved and planned for pedestrians and are often created and used by some pedestrians, such as marginalized individuals, adolescents, and dog walkers to reach desired destinations more quickly. But this is largely true only during daytime while at night, desire paths can be associated with a lack of safety (Batchelor et al., 2016; Kowarik, 2018).

In both case studies, most vacant lands include desire paths, which are used for detour and informal activities. Identifiable examples are crossings over train tracks, desire paths in Markham's Rouge Valley, and desire paths to the north of Fairview Public School and Karya Park in Downtown Mississauga (Coutts et al., 2019; Google, 2023). A design proposal for a vacant land in Downtown Mississauga uses existing desire paths to identify openings for pedestrians between proposed buildings (Green Infrastructure Foundation, 2018). All these design proposals emphasize placing people in natural and semi-natural open spaces and providing linkages to existing pedestrian routes in surrounding sites.

Despite the considerable area of the vacant lands, these spaces are not mentioned in the official plans of the case study municipalities. Meanwhile, the perception of residents about these sites is negative, typically associated with decreasing property value, being useless and valueless, including undesirable weeds and scrubs, and being disturbing and ugly. However, a disregarded aspect of vacant lands is their potential use as GI habitats and pedestrian routes/destinations before development. Depending on the size of the site, duration of abandonment, and level of soil sealing, these areas can develop unique urban habitat structures at diverse stages of plant development. This provides retreats for plants and animal

species and improves local biodiversity. The species are mostly ruderal and without a specific habitat requirement. Endangered species can be found in vacant lands as well. Importantly, the development of GI in vacant lands can improve the perception of residents about these spaces over time. (G. Kim et al., 2015, 2018; Mathey et al., 2015, 2018; Vecchio & Arku, 2020).

4.6.4 Natural Corridors (NCs)

NCs in cities are expected to harbour plant and animal species as well as humans so that they can contribute to both GI and pedestrian connectivity. In the case studies, restoration of natural processes, introduction of trails, and provision of pedestrian-oriented facilities are the main interventions in NCs. Downtown Mississauga City is entirely built over formerly farmlands. As a result, there are no preservation areas within the city centre. Due to its highly built-up area, there are only a few parks and green spaces near Downtown Mississauga. The major NCs are block-size parks around the centre's perimeter, which perform as pedestrian gateways to enter the centre (City of Mississauga, 2010). In Downtown Mississauga, GI interventions are focused on providing pedestrian access as well (e.g., creek interventions in Downtown Mississauga).

However, pedestrian-related interventions may change over time due to the incremental implementation. For example, the planned Rathburn pond in Mississauga is expected to pre-treat temperature, pollution, speed/volume of the stormwater from the parking lots before it discharges into Cooksville Creek. While this area was primarily intended to improve the neighbourhood by including a civic centre and a play area, the public area of the pond has been reduced during the implementation and a play centre made into a for-profit private with no public access (City of Mississauga, 2010, 2013; Google, 2023).

Sheridan College in Downtown Mississauga is an important example of co-developing pedestrian routes in parks because of its unique design approach. It is an open space called Scholars' Green, which includes both GI measures (tree canopies and pervious pavements) and pedestrian paths aligned with the green spaces in their neighbouring blocks. Scholars' Green, shown in Figure 4-11, is a part of a major intervention for creating both GI and pedestrian connectivity in some areas of Downtown Mississauga, including Rathburn square to the north, a community common to the west and the Main Street common in the east. This is accomplished through continuous corridors of both green spaces and pedestrian pathways (Mississauga Interviewee #1) (City of Mississauga, 2010).

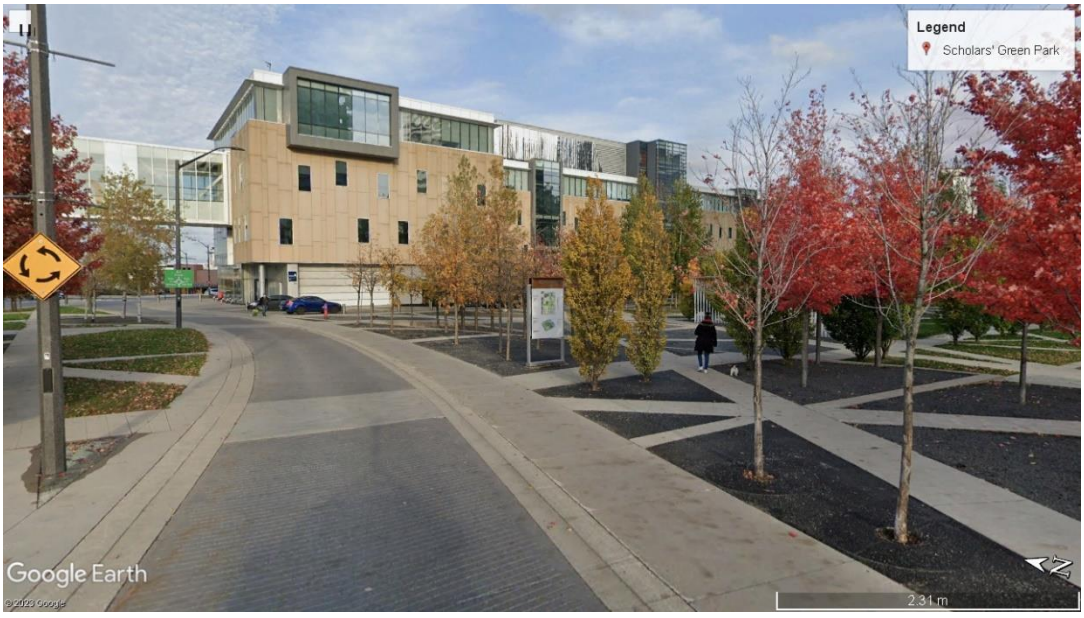


Figure 4-11 Scholar's Green in Downtown Mississauga (Google Earth)

In contrast to the entirely build up environment in Downtown Mississauga, Markham Centre is built over released greenbelt lands, including protected greenbelt, farmlands, and a few settlements, which run continuously through the centre. This is shown in Figure 4-4. Despite serving as a backbone for Markham's natural assets, the NCs in Markham Centre create voids in the developed areas. NCs in the Markham Centre are accessible to the public through two alternatives, buffer zones and trails. Firstly, the buffer zones serve as public parks for pedestrians and are meant to have urban design characteristics for non-intensive pedestrian use. For example, they require a finished level of materiality as well as playgrounds that can withstand more wear and tear (Markham Interviewee #2). Secondly, the City of Markham has been planning for the three sets of trails in the Rouge Valley since 2004 under the Markham Centre Greenlands Master Plan. This plan is meant to have minimum impact on the valley by controlling the invasive species and similar practices (Markham Interviewee #2). Parts of these trails were constructed by 2020 and the remaining ones were under environmental assessment throughout 2021 (Markham.ca). Through these strategies, NCs, in Markham Centre, can improve the physical continuity of pedestrian corridors and increase their density by being strategically accessible to pedestrians.

However, the Rouge Valley is not a wide and robust system, and the buffer zone is not large enough for unlimited public access. One respondent from the City of Markham states: *"... having this open space system and the Greenlands Plan that is accessible to the public, I think that's a huge amenity. The downside of course is there is going to be a rather significant population here and that creates additional stresses to the environment."* Accordingly, general access to the Rouge Valley is limited to passive

recreation and education for protection purposes as one respondent states: *"there is a delicate balance there... to provide opportunities for the public to access where they can access and identify the areas that are sensitive and should be not available for public access" (Markham Interviewee #3;* #4).

Both case studies intend to convey pedestrian movement by providing access to NCs. In Downtown Mississauga, the implementation is incremental and subject to the change of priorities. Moreover, individual projects are not coordinated for creating pedestrian connectivity between different amenities of NCs. In Markham Centre, multi-user trails in the Rouge Valley provide an alternative solution to connect the fragmented neighbourhoods, which influence the protected lands less than road crossings. However, despite recent efforts for designing low-impact trails and increasing public education on reducing environmental damage, public access is deemed harmful for the protected area, which has undermined the potential of these trails for improving pedestrian connectivity.

As this dissertation seeks to identify the implementation gaps in developing both GI and pedestrian connectivity in areas under intensification, this section studied the provision of GI and pedestrian connectivity in both case studies to discuss their flaws in the following section. It is evident that the integration of GI and pedestrian connectivity has not been realized yet in both case studies. However, developing GI and pedestrian connectivity co-occurs in identified UPOSs even though the case studies are different in the distribution of natural features and the urban design features of pedestrian environments (e.g., the location of sidewalks with respect to roads, the existence of frontages, the distance between destinations, etc.). In the next section, the current plans and implementation strategies are criticized to identify design-based gaps of the realization of an integrated network of GI and pedestrian connectivity in the case studies.

4.7 Planning and Implementation Gaps

In the previous sections, a need for developing an integrated network of GI elements and pedestrian-oriented facilities in UPOSs to enhance both GI and pedestrian connectivity in areas under intensification was identified. This assertion is based on the flaws observed within the municipal case studies, whereby current approaches to the provision of GI and pedestrian networks are limited while both GI and pedestrian networks are created in shared UPOSs. In the following section, the design-based gaps for integrating GI and pedestrian connectivity are discussed, which are found from interviews, official plans, and direct observations.

4.7.1 Barriers to GI implementation in Municipalities

Although both municipalities have developed interventions to include GI features in their masterplans, these interventions have not been implemented completely. In this section, we list several identified barriers that obstruct the implementation of GI plans in municipalities.

1) Complexity of Government Structures

The complexity of government structures can hinder an effective collaboration between key stakeholders. While GI offers clear environmental and social benefits, its successful integration into urban development requires coordinated efforts between planners, urban designers, ecologists, engineers, landscape architects, and developers. Often, these groups operate independently. As a result, opportunities for cross-disciplinary collaboration remains limited. The interviews revealed miscommunication and limited opportunities for collaboration between departments. As a result, GI is considered as an afterthought in the strategies, rather than a core component of urban design. This issue significantly slows down GI implementation.

2) Developer Preferences

Another key barrier is associated with the conflicts between developer goals and the public sector's sustainability objectives. Developers are primarily driven by market demands and profitability, which often leads to prioritizing high-density development with minimal consideration for GI. This is evident in the case of Downtown Mississauga, where GI proposals by the masterplan have been replaced by developers for profit and private projects. For example, Rathburn pond on Northwest of Downtown Mississauga is replaced by an amusement park. In other cases, GI elements are viewed as non-essential or decorative, rather than integral to the design of resilient urban environments. As another example, a greenfield vacant land development to the North of Burnhamthorpe Rd in Downtown Mississauga, where the developer's plans significantly differ from the Downtown21 masterplan, and most GI features are replaced by high-rise towers. Finally, in the case of Markham Centre, where the scale of developers' projects is larger, the developers implement GI features within closed development boundaries, but these development clusters are isolated from the neighbouring natural features.

3) Funding Constraints

In addition to the structural challenges within municipalities, funding remains one of the most significant obstacles for developing GI on large scales. Nature based solutions are cost-effective in the long term in delivering ecosystem services while requiring higher initial investments compared to conventional infrastructure. However, budget constraints lead to prioritizing projects with immediate economic returns or essential services provision over GI initiatives with longer-term and less visceral benefits. An example

of these limitations in Downtown Mississauga is the implementation of limited number of street trees. An example of budget constraints in Markham Centre includes limited funding for burying electricity distribution cables.

4.7.2 Design-based Gaps to Integrate GI and Pedestrian Networks

"Good urban design" can develop both GI and pedestrian connectivity in intensification planning through design guidelines that create an integrated network of GI and pedestrians in UPOSs. As one respondent mentions, "*Good urban design is how you do it. I don't know how the green infrastructure can alone create connectivity... If you don't have good urban design in any community, there is going to be really little that you can do to fix that."*

The case study research and interviews with City staff found that planning for GI and pedestrian networks is often implemented in a piecemeal fashion, with limited design options and lack of overall design guidelines. This is particularly challenging in areas under pressure from the intensification development. The design strategies that can develop both GI and pedestrian connectivity in areas under intensification are limited. Interviewees list energy concern, LEED requirements for new projects, Transport Demand Management (TDM) measures, parking standards, and pilot projects with permeable pavement as the only available urban design strategies and tools for sustainability issues (Markham Interviewee #3; #5; Mississauga Interviewee #4). In the following, the barriers to developing design guidelines for an integrated network of GI and pedestrian in both case studies are presented.

1) Lack of a Clear GI Typology

Recent research has generated an array of GI elements that are appropriate for urban areas. However, the site visits and interviews of this study reveal that apart from natural corridors and parks, GI elements in the UGCs are limited to the traditional types of green spaces. These elements include mown lawns without draining substrates, scattered street trees/hedges with minimal species' diversity, and a few bioswales (a small number exist in surface parking areas of Markham Centre). In NCs, pedestrian trails are often comprised of limestone screenings rather than impervious surfaces, as these GI elements are the only pervious pavement in the respective municipalities (Markham Interviewee #3). This reveals a lack of translation between GI typologies from the literature and GI elements in official plans of both case studies. Although there is a growing recognition of green roof programs in both Markham and Mississauga, other GI measures that are currently promoted in the literature for developing in compact areas (e.g., street verge vegetation and pervious pavements) are absent in the official plans of case studies (Markham Interviewee #2; City of Markham, 2020; City of Mississauga, 2010).

2) Lack of Acknowledging the Range of Ecosystem Services Provided by GI

As noted in the literature review chapter, the benefits of a GI network are aligned with intensification goals. However, in the official plans of the case studies, only a few ecosystem services, including water regulation ecosystem services have been recognised and other ecosystem services of GI, such as reducing the heat island effect, decreasing environmental pollution, and promoting public health are not addressed. The design tools to address ecosystem services in the official plans are exclusively used to deliver water regulating ecosystem services, such as LID, stormwater management, and LEED certification. Case study analysis and interviews revealed that water regulation is addressed in detail and the interviewees are knowledgeable about the design tools. One interviewee demonstrates their familiarity with the water regulation process: *"... you can see that there is some bioswales around and through some of these parking lots. So that's a part of it to help to deal with the stormwater issues and again through the LEED and other individual approvals, the bottom line for the stormwater is to be held on-site and then its released flood held on the rooftops and then used for greywater and irrigation...*" (Markham Interviewee #2). However, tools to address other ecosystem services receive much less attention since there is a lack of recognizing them in municipal plans. Moreover, Indigenous perspectives are absent in the design of GI and pedestrian networks from masterplans of the case studies. The current plans lack elements that reflect or acknowledge the cultural and historical connections of Indigenous communities to the land. This omission is particularly relevant in areas where such connections could provide meaningful insights into sustainable design practices.

Integrating an Indigenous lens into GI planning can enhance the cultural relevance and inclusivity of urban spaces. This might include incorporating traditional ecological knowledge (TEK) into the selection of plant species, the layout of green spaces, or the creation of interpretive features that acknowledge the historical use of the land. For example, the inclusion of Indigenous art, storytelling spaces, or interpretive signage can serve as both an educational tool and a tribute to the enduring legacy of Indigenous peoples.

3) Lack of Defining the Structural Characteristics of GI Elements

Designing for GI connectivity requires compatibility with local variables, such as water tables, temperature, humidity, and soil type as well as native species (Saboonian, 2014). However, as these variables differ between locations, it is challenging to generate design guidelines in different locations for developing GI elements (e.g., sidewalk material, depth of bioretention soil, exact plant species, etc.). Studies suggest that to define general design guidelines for implementing GI in various cities, in comparison with detailed local variables, the structural characteristics of GI elements are more useful. These characteristics include the area, height, and width of GI elements in UPOSs, which have recently

been utilized in the literature for presenting climate sensitive urban designs (Cortesão, Lenzholzer, Klok, et al., 2020; Cortesão, Lenzholzer, Mülder, et al., 2020; Tamminga et al., 2020). However, design guidelines for such structural characteristics have not been developed in the studied UGCs.

Both UGCs are in the prototype stage of developing detailed local variables. One respondent points out: "*we tried a couple of things that didn't work out. We tried a creative stormwater management system where cells were clogged up with dirt and mud and had to go back to the traditional pond. We also had pervious paving here in a parking lot associated with a car dealership site, which clogged and didn't work. So given the types of soils we have, here at the high water-table level that we have, there are a lot of challenges in terms of being able to do things that you might be able to do in the other parts of the city or GTA*" (Markham Interviewee #5). The example of dealing with detailed local variables can be seen in Markham's Green Road project, which studies the performance of permeable asphalts under plowed snow and sand, impact of salt and debris on bioretention facilities, and use of native grasses and perennials (Markham, 2018).

While the master plans and streetscape plans for the case studies discuss landscaping details, such as plant species and depth of the substrates, they lack guidelines for the structural characteristics of GI elements. For example, in Downtown21, although the street designs for the arterial and collector roads discuss street trees, the size of these trees is not defined. The street designs also include medians and vegetated street verges, but it is not clear whether the structure of surface coverage is either elevated shrubs of vertical trees or horizontal grass. Moreover, there are no design details about how these green spaces are shared with street parking spaces and property access aprons. One of few instances of structural description of GI elements is the explanation about street trees in streetscape manual of Markham Centre, where the maximum height and crown area of different tree species are identified.

4) Lack of Providing Safety and Attractiveness in Pedestrian Routes

Both case study municipalities are aware of the importance of safe and physically enticing walking environments for pedestrians. As an example, in a survey concluded in Markham Centre, 42% of respondents highlighted the lack of safe-walking infrastructure as a priority issue in the city centre. However, safety and attractiveness of pedestrian environments are not comprehensively projected in plans and there is a lack of design details for the interventions that can promote pedestrian activities. Proposed design strategies for increasing these two characteristics in the case studies include streetscape design and LEED standards for new buildings in Markham Centre as well as street parking in Downtown Mississauga. However, these strategies are rarely implemented, and the lack of safety and attractiveness

has been only addressed by implementing vehicle speed limit measures and street furniture (City of Markham, 2020, 2021; City of Mississauga, 2010, 2019; Google, 2023).

For enhancing pedestrian safety and the appeal of the built environment, the strategies that are often identified in the published work tend to focus on the implementation of GI and the promotion of underutilized lands. In the literature, GI measures are acknowledged as major contributors to the provision of safety and attractiveness. Importantly, over the last decade, numerous studies investigate the impact of GI measures on improving pedestrian environments, including increasing traffic and neighborhood safety in UPOSs. However, this potential is not taken advantage of in the case studies and the GI implementation in pedestrian routes of case studies is limited to landscaping pedestrian pathways with beautiful plants, and temporary green installations.

In both case studies, the attractiveness and safety of the public realm for pedestrians are overshadowed by the focus on enhancing the physical continuity of streets and pedestrian routes. Although these two characteristics have recently been listed in the plans for both centres, public interventions for promoting them, such as enhanced tree canopy, LEED Neighbourhood Design, public arts, cultural attractions, recreational facilities, as well as architectural features/facades are rarely implemented. Current interventions in both centres lack design guidelines and do not identify potential locations for their implementation (City of Markham, 2021; 2020; Mississauga, 2010).

5) Lack of Addressing Human-scaled Walking Environment

A major barrier for creating walkable environments in areas under intensification is that both horizontally large-size urban blocks and vertically high-rise buildings create exterior environments that are not at human scale, creating unpleasant pedestrian environments. The continuous and long frontages of large-size urban blocks as well as large plazas of high-rise buildings do not create human-scale environments and pedestrian destination due to monotony, excessive distances between destinations, limited points of interest, safety concerns, and lack of comfort amenities (Francis et al., 2012; Gehl, 2013). Despite the intention of both Mississauga and Markham to promote human-scaled development through design strategies, there is a lack of design details for their proposed strategies, such as developing mid-rise buildings and building setbacks. One significant design strategy from the recent literature for creating a sense of human scaled development is the inclusion of GI, such as green facades and terraced green roofs in buildings to articulate the space through breaking the monotonous facades and adding visual interest and biodiversity to the urban environment (Tamminga et al., 2020).

6) Lack of Promoting Different Purposes of Walking

Another overlooked aspect of pedestrian movement in the case studies is that recreational walking and utilitarian walking are not distinguished, and recreational walking is not promoted in their plans. The plans in both Mississauga and Markham exclusively focus on providing destinations for utilitarian walking and maintaining comfortable walking distances. However, recreational walking or exercise walking does not need a specific destination since the purpose of it is to be in UPOSs and have access to a range of activities, such as exercising, socializing, sightseeing, and eating (City of Markham, 2021; Forsyth, 2015; Forsyth et al., 2007; Kang et al., 2017).

Various design strategies, such as promoting public art and developing gathering spaces can encourage recreational walking and create non-residential destinations for pedestrians (Grabow et al., 2019). These interventions are gradually being incorporated in the planning documents of both case studies. For example, Mississauga acknowledges the value of public art and streetscape design for pedestrians in its plans. Similarly, in Markham Centre, 53% of participants in a survey argue that creating public gathering spaces is a prominent issue for Markham Centre (City of Markham, 2020; City of Mississauga, 2010).

The incorporation of GI elements, such as high green views, tree canopy cover, and remote trails in the UPOSs promotes recreational walking since it transforms these spaces into park settings and stimulates active contact with nature (European Commission's Directorate-General Environment, 2012). The use of such spaces during the COVID-19 pandemic has increased by roughly 300% (Venter et al., 2020). However, there is a lack of design guidelines in the plans of both case studies that can support different purpose of walking.

4.7.3 Financial Barriers to Integrate GI and Pedestrian Networks

Including GI elements in public infrastructure projects can add substantial costs. As noted earlier, pilot green street project in Markham had a capital cost of 25-30% more than a typical comparable street project, due to the incorporation of GI elements (Markham, 2018). Given the uncertainty in the cost burden of GI elements, public projects that include GI may be postponed or cancelled. For example, upgrading the Highway 7 sidewalks was a major component of intensification planning in Markham Centre, but some of the upgrade opportunities were not realized due to financial limitations. As an urban planner from City of Markham recalls, "*there is always a level of give and take. You implement some ideas, and some are left for down the road. Here [alongside Highway 7] we have massive overhead hydro poles and wires. It's just such an expensive proposition to bury those, and it's un-funded... we haven't been able to afford to bury. The character and the ambience of that street would be very different if you weren't overwhelmed by the massive hydro poles*" (Markham Interviewee #1).

Although cost-related barriers are not directly addressed by this study, it is expected that creating design solutions for the simultaneous development of GI and pedestrian connectivity can help to provide a planning vision for governments and municipalities, such that they can allocate funding in areas under intensification as appropriate for their jurisdictions. Financial barriers to implementing of GI and pedestrian networks can be overcome by developing design guidelines that specifically identify how both GI and pedestrian connectivity can be included in intensification planning.

As this dissertation argues that for blending GI and intensification, GI and pedestrian networks can co-occur in shared UPOSs, this section provided evidence that both Mississauga and Markham are invested in developing GI and pedestrian connectivity in their UPOSs. However, the actual implementation of GI and pedestrian connectivity is extremely limited. It was further shown that due to design barriers, the case study municipalities are not capitalizing on the potential of GI networks to deliver ecosystem services nor that of pedestrian networks to provide walkability. In identifying these barriers, it is argued that designing for GI and pedestrian connectivity in a coordinated approach can more effectively achieve ecosystem services and walkability in the UPOSs of intensification areas than designing for each in exclusion. Accordingly, the following section provides urban design tools for integrating GI elements with pedestrian networks in shared UPOSs.

4.8 Addressing the Identified Gaps by Blending GI and Pedestrian Connectivity in UPOSs

To address the design barriers of integrating GI elements with pedestrian networks in shared UPOSs, this section develops urban design tools. This includes two tabular tools that are adapted for developing GI in compact/intensified urban environments as well as a design proposal that demonstrates this integration. For the tabular tools, a significant body of published work regarding implementing GI elements is reviewed to be leveraged as a tool to resolve the design issues identified in the previous section. Tabular tools have recently gained momentum among GI and urban ecosystem services researchers for practical applications since they can connect various aspects of GI planning (e.g., GI elements, ecosystem services, etc.) to different areas of urban design (e.g. landscape types, development scale, etc.). For example, Ronchi et al. (2020) present a tabular tool, which relates GI elements and landscape types to the improvement of the performance of urban ecosystems in Milan, Italy metropolitan area. In the following, a more in-depth description of method, limitations, and components of the toolset used for this study is provided.

The proposed toolset addresses the identified design issues in the planning of UGCs. These tools have been developed in response to the identified urban design gaps for integrating GI and pedestrian networks in the potential UPOSs. It is comprised of three components:

- a table categorizing GI typologies that can be implemented in urban settings, Table 4-2;
- a comparative table identifying interactions between GI and grey infrastructure and outcomes of these interactions, Table 4-3; and
- a design proposal that generally illustrates the integration of GI and pedestrian connectivity in intensifying UPOSs. The design proposal is informed by the two tables and is intended to recommend structural details for application in any given scenario while leaving landscape details to be included on a case-specific basis.

The GI typology table addresses the first and second identified deficiencies. To address the lack of GI typologies in the official plans of UGCs, the GI typology table offers a set of elements that planners and urban designers can apply to the design of UPOSs in intensifying areas. The GI elements are selected if they fit in intensified areas and can provide public access. The UPOSs for each GI elements is based on their stated implementation space in the literature.

To address the lack of knowledge around GI capabilities for providing multiple ecosystem services, the second table identifies the relation between ecosystem services and disservices of GI elements and their structural properties. The table's content has been compiled from previous studies, which show the placement of GI elements in UPOSs determines the delivery of ecosystem services or disservices. For the third issue, which identifies the need to focus on the structural properties of GI and UPOSs rather than ecological design elements applying the two tables in the design proposal can be beneficial.

To address the fourth deficiency, where safety and attractiveness for pedestrian connectivity are not fully considered in urban design, these qualities of pedestrian corridors are approached as cultural ecosystem services. Therefore, in Table 4-3 the safety and attractiveness of pedestrian environments are viewed through the lens of positive or negative ecosystem service delivered by GI elements. To address the existing lack of human-scaled pedestrian environment, the design proposal offers some urban design and architectural solutions from the literature. To address the sixth issue, whereby promoting different purposes of walking is overshadowed, the design proposal illustrates GI elements as physical environmental features to transform UPOSs into destinations for pedestrians and to provide recreational walking.

4.8.1 A GI Typology for UPOSs

Table 4-2 proposes a GI typology for intensified urban areas. It is comprised of a collection of GI elements that can be placed in UPOSs and produce urban ecosystem services. The table is composed of four columns. The first column categorizes GI elements based on their structural properties, including

volume, height, area, and dependency on other structures. The second column of Table 4-2 lists the GI elements with similar structures for each category. For example, vertical greens and tree canopies are both placed above ground. Therefore, they are listed in the category of vertical elements. In the third column of Table 4-2, the potential UPOSs to contain each GI element are highlighted. This inclusion is based on whether the support structure or an area for a GI element is available in a particular UPOS. For example, green walls and green roofs are not suitable for NCs because there are no buildings there to support them. The last column describes each GI element and provides examples of each in the built environment, as well as the ecosystem services they can deliver. Note that the GI elements and UPOSs are alphanumerically coded in Table 4-2 for easier reference. For example, Bioswales along an ARH can be represented as (12-a).

The GI typology table is useful when a group of ecosystem services is needed in a limited urban space. For example, based on this table, vertical elements may be quickly identified as the only option to suppress traffic noise along ARHs. To create GI connectivity in areas under intensification, the GI typology table can assist urban designers and planners to select the GI elements that can both structurally fit in each UPOS of UGCs as well as provide the needed ecosystem services of that UPOS. This can be accomplished in three steps. Firstly, needed ecosystem services in each UPOSs are prioritized. Secondly, applicable GI elements are identified. Finally, the available area in each UPOS is designed with a set of GI elements in a continuous and/or stepping-stones fashion so that they can deliver the prioritized ecosystem services.

Because of the limited available UPOSs in a compact urban environment, multifunctionality and pedestrian accessibility are key characteristics required for the GI elements in Table 4-2. To prioritize multifunctionality, GI elements that serve only one purpose are excluded from this table. For example, temporary planters are excluded because they are only used for temporary beautification purposes and do not contribute to other ecosystem services. GI elements that are of lower ecological value are likewise excluded – key among these are street verge grass lawns, due to their limited contribution to ecosystem services and high-water consumption. To prioritize pedestrian accessibility, GI elements that are not accessible to the public such as conservation areas (not accessible to all pedestrians) and allotment gardens (only used by subscribers and members) are excluded from this table, despite providing a rich variety of ecosystem services as they do not contribute to pedestrian movement.

4.8.2 Demand for Ecosystem Services in UPOSs

The second table of the toolset, Table 4-3, has two components. It prioritizes the demand for ecosystem services in each UPOSs and demonstrates where the interaction between GI and the built environment

generates benefits for urbanites. The demand for ecosystem services is prioritized based on UPOSs as each UPOS requires specific ecosystem services for addressing its urban issues. The provision of ecosystem services also depends on UPOSs as the interactions between GI elements and the surrounding environment (physical environment of UPOSs) lead to the delivery of the ecosystem services or disservices.

Table 4-3 includes two leftmost columns, a header row, and intersection cells. The leftmost columns list the main categories of ecosystem services adopted from the widely used TEEB typology (Food and Agricultural Organization of the United Nations, 2022; TEEB, 2011). The header row consists of the four categories of UPOSs. The intersection of these two creates cells that contains information about a single ecosystem service, which is specified by parenthesis. The demanded ecosystem services for each UPOSs are highlighted in grey cells. Moreover, the interactions between GI elements and the surrounding environment are marked with "+" and "-" signs, for ecosystem services or disservices respectively. In Table 4-3, the demand of ecosystem services is determined based on both articles and case studies while the delivery of ecosystem services/disservices are discovered by reviewing articles. Note that the cells in Table 4-3 are numerically coded for convenient referencing. For example, the noise absorption ecosystem service, which can be provided by GI elements, is referred as (32).

In general, the demand for ecosystem services is defined by both the perceptive demands of urban residents and addressing urban issues. For the former, a recent survey-based research trend deals with the supply and demand of ecosystem services (Hui & Jim, 2022). However, these studies reflect the perception of local residents so that their outcomes are case specific, and their results have limited applicability in other cities (Drillet et al., 2020). For example, residents of Berlin, Germany are acceptable of wild-grown vegetation (Kowarik, 2018), whereas such vegetated areas are generally perceived as untidy, unpleasant, and lacking cues of care (Kowarik, 2018; Loder, 2014; O'Sullivan et al., 2017; Yuqing Tian et al., 2020). For the latter, by focusing on urban issues in the UPOSs, the urban issues associated with intensification are general and applicable to other compact cities and areas under intensification (Conticelli et al., 2017; McFarlane, 2016).

To identify the demand for ecosystem services in case studies, the municipal issues and their planning priorities were investigated during the interviews. For instance, it was expressed in the interviews that water regulation is a priority for natural corridors in Mississauga because urban creeks are mostly modified, and their water infiltration capacity is reduced (Mississauga Interviewee #1). Municipal priorities were also identified from their planning documents. This dissertation further identified demand for ecosystem services using publications about urban issues in city centres and intensified urban areas.

For example, in reviewing multiple publications on urban issues, it was found that air pollution issue along high traffic arterial roads is frequently brought up (Tillie et al., 2018; Tiwary & Kumar, 2014; Wolch et al., 2014).

The incorporation of GI elements in UPOSs may lead to ecosystem disservices due to two main reasons. First, the placement of certain GI elements in UPOSs can result in undesirable conditions for humans. For example, wild grown species in undeveloped lands can reduce the attractiveness of a space for pedestrians because they are interpreted as a sign of neglect, untidiness, and disturbance of the cityscape (Mathey et al., 2018). Second, the structural interactions between intensified urban environments and GI elements may block the flow of nutrients and result in reduction of ecosystem services. For example, compacted ground beneath ARHs and CLRs blocks the infiltration of water from longitudinal structures such as pervious pavements (Cidlowski et al., 2015). As another example, the vertical elements such as trees and greenwalls adjacent to high rise buildings in high traffic ARHs, block the movement of air and result in reduction in air purification ecosystem service (Abhijith et al., 2017; Pugh et al., 2012; Tomson et al., 2021).

Ecosystem services/disservices are important in designing pedestrian paths because they influence route choice for pedestrians. For example, paths are placed as at a distance away from arterial roads so that the air filtering property of GI elements reduce the air pollution for the pedestrians (Abhijith et al., 2017). Table 4-3 assists urban designers and planners to provide the needed ecosystem services in different UPOSs by integrating GI in UPOSs such that the provision of ecosystem services is maximized, and ecosystem disservices are minimized while enhancing walkability in city centres.

Note that only regulating and cultural ecosystem services are studied in Table 4-3 for two reasons. First, the demand for the regulating ecosystem services and cultural ecosystem services of GI is significant for pedestrians in compact built environments because these ecosystem services improve environmental conditions of the pedestrian realm (e.g. air quality, noise levels) and may persuade people to choose to walk. Importantly, the promotion of physical activity is included as part of cultural ecosystem services by expanding the cultural ecosystem services to include safety and attractiveness. (Breuste & Artmann, 2020). Second, there is a limited amount of research that addresses provisioning and supporting ecosystem services in compact urban environments.

On another note, in some instances, ecosystem services may not be limited to a certain type of UPOSs. For example, air filtration takes place in a vicinity of GI elements because it is caused by the interaction between GI elements and the flow of air. Therefore, this service is needed where the air pollution is an urban issue. In contrast, balancing CO2/O2 is caused by the absorption of CO2 and release of O2.

Therefore, the precise location of GI elements is not important for this ecosystem service and its benefits are delivered everywhere.

The interactions in Table 4-3 should be accounted for in the urban design of areas under intensification to ensure the continuation of ecosystem services and enhanced walkability of city centres. As cultural ecosystem services are a priority for all UPOS, the location and width of the pedestrian paths with respect to its surrounding environment (e.g., lateral separation from buildings, distance from motorized traffic, etc.) are designed first and then the remaining area is covered with GI elements.

Table 4-2 Spatial Classification and Description of GI elements

Structural properties	GI Elements	UPOSs				Description Example Ecosystem Services
		ARH (a)	CLR (b)	USPL (c)	NC (d)	
Vertical Elements	Green walls (1)	■	■	■		Vertical arrays of plant species attached to building facades (Jim, 2015) Vegetated pergolas, climbing plants (Tamminga et al., 2020), Meshed green facades (Pérez et al., 2014) Climate regulation, evapotranspiration, noise reduction, aesthetic, and recreation
	Vertical greens (2)	■	■	■		Planted strips of shrubs and trees that act as a wind buffer to reduce soil erosion while providing wildlife habitat Vegetation belts (Pérez et al., 2016), vegetation barriers (Morakinyo & Lam, 2016), Hedges (Abhijith et al., 2017) Noise reduction, air filtration, evapotranspiration, traffic safety, art installation
	Tree Canopy (3)	■	■			Tree crowns on a vertical distance from the ground Individual trees, mature urban trees, trees in green streets Recreation services, water regulation, climate regulation, providing shade, reduce crime (McPhearson et al., 2016)
Dependent Structures	Underground parking (4)		■	■		Buried parking spaces that reduce emission from cars. Single car ramped garages, multi-level underground parking, Noise reduction, aesthetic, pollution reduction (Cui & Nelson, 2019; Höglund, 2004)
	Rain Tanks (5)		■	■		Harvesting rainwater in containers for alternative purposes. Plastic tanks, barrels connected to gutters Pollution reduction, erosion control, stormwater regulation (D. Kim & Song, 2019; Schubert et al., 2017)
	Downspout Disconnect (6)	■	■	■		Disconnecting downspouts from storm drains to create detention capacity Gutter to lawn, connecting downspouts to rain barrels. Water regulation, stormwater management, erosion control (Bednar & Henstra, 2018; Voter & Loheide, 2018)
	Private/public interface of green spaces (7)	■	■			Connecting private landscapes and public spaces Easement gardening (Hunter & Brown, 2012), removed footpath to support understory gardens (Marshall et al., 2019) laneway backing into the lots (Xu, 2017) parks backing into private yards Water regulation, biodiversity, pollination, aesthetic, sense of safety (Krauze & Wagner, 2019)
	Openings between buildings (8)	■	■			Spaces between buildings, integrated with green features permeable to pedestrians to movement Green alleys, openings in facades, uncovered/covered spaces Climate regulation, aesthetic, recreation (Black et al., 2016; Costa & Lopes, 2015; Newell et al., 2013; Salata & Yiannakou, 2016; Savvides et al., 2019; Yang et al., 2020; Zuniga-Teran et al., 2020)
	Pervious Pavements (9)	■	■			Finishing pedestrian or traffic surfaces with porous material, which allow water to infiltrate into the ground. Cobble stones, gravel pavers, permeable asphalt, permeable concrete, permeable interlocking, etc. Water regulation and noise reduction (Bichajło & Kołodziej, 2018; Sprouse et al., 2020; Wise, Braden, Ghalayini, Grant, Kloss, MacMullan, et al., 2010)
	Green roofs (10)		■			Covering portions of rooftop area with vegetation Intensive, extensive, and naturalized green roof Reduce urban runoff, provide noise reduction, climate regulation, aesthetic, pollination, recreation (Langemeyer et al., 2020; Mesimäki et al., 2019)
	Riparian Zone (11)				■	Buffer areas around un-channelized streams and lakes hosting specialized vegetation containing pathways for views and access (Cao & Natuhara, 2020; Gkiatas et al., 2021; Ignatieva et al., 2011; Kondolf & Pinto, 2017; Zaimes & Iakovoglou, 2021) Grass, herbs, shrubs, and wooded buffers, wetlands Pollution regulation, water regulation, stromwater management and speed reduction, erosion reduction, biodiversity, aesthetic, and recreation
Low Profile Structures	Bioswales (12)	■	■	■		Vegetated swales alongside the roads to pre-treat and slowly release urban runoff to sewer systems (Woznicki et al., 2018) Dry swales, wet swales, grassed channels Water regulation, climate regulation, air quality control, aesthetic, recreation
	Rain garden (13)		■	■		Extensive vegetated ground depressions to collect, infiltrate, and filter runoff. Rain gardens from 10s to 1000s of square meters in size (Christman et al., 2018), drained/ self-contained rain gardens Water regulation, climate regulation, evapotranspiration, aesthetic (Jia et al., 2016)

	Mowed street verge Areas (14)					Managed turf grass and lawns that permit unobstructed infiltration of water despite the type of vegetation (Kazemi et al., 2011) Vegetation in street verges, medians, easements, below trees, swales, and between paving joints (Säumel et al., 2016) Water regulation, climate regulation, aesthetic, and recreation
	Wild grown vegetation (15)					Un-maintained/ guerilla gardened road verge vegetation and trees (Säumel et al., 2016) Flower beds in street verges, native/non-native combination of trees (Kowarik, 2018; KOWARIK, 2021; Kowarik et al., 2021) Enhanced climate regulation, air regulation, water regulation, evapotranspiration, pollination, biodiversity, and aesthetic
longitudinal Structures	Xeriscaping (16)					Sustainable landscaping using indigenous plants and water-efficient irrigation (Meyer et al., 2014; Nolon, 2016) Drought-tolerant plants, limiting turf area, use of mulches to retain soil humidity Climate regulation, biodiversity, water regulation, pollination.
	Vegetated train tracks (17)					Vegetated surfaces along railroads Conversion of abandoned railroads, green tramways in densely built-up areas (Heins, 2015; Lyytimäki & Sipilä, 2009; Sikorski et al., 2018) Noise reduction, water regulation, biodiversity, climate regulation
	Greenways (18)					A shared often along wide natural features not intended for motorized vehicle use Linear parks, paths along creeks, paths along railroads, utility corridors, natural corridors Climate regulation, air quality regulation, aesthetic, and recreation (Ellis et al., 2016; Lynch, 2019; Walmsley, 2006)
	Pervious Pavements (19)					Finishing pedestrian or traffic surfaces with porous material, which allow water to infiltrate into the ground. Cobble stones, gravel pavers, permeable asphalt, permeable concrete, permeable interlocking, etc. Water regulation and noise reduction (Bichajło & Kołodziej, 2018; Sprouse et al., 2020; Wise, Braden, Ghalayini, Grant, Kloss, MacMullan, et al., 2010)
Spatial Structures	High Quality Parks (mixed use dev.) (20)					Compact urban parks with a divers range of species, significant landscaping quality, pedestrian-oriented facilities, and amenities (Hughey et al., 2016; Pauleit et al., 2019) Large urban parks, pocket parks, neighbourhood green spaces Climate regulation, water regulation, air quality control, biodiversity, aesthetic, and recreation
	Natural Heritage Parks (21)					Natural environments in pristine condition with native species Protected areas, conservation parks All regulating and cultural ecosystem services (Dobbs et al., 2014; Dorning et al., 2015)
	Blue spaces (22)					Bodies of water within urban environments (Pauleit et al., 2019; Plieninger et al., 2013) Stormponds, ponds and lakes, rivers and creeks Water regulation, biodiversity, climate regulation, aesthetic, and recreation
	Uncovered soil (23)					Implementing bare soil left for spontaneous succession of vegetation (Sikorski et al., 2018) Water regulation and biodiversity.

Table 4-3 Demand for Ecosystem Services in the UPOSs

Ecosystem Services		Urban Public and Open Spaces			
		Arterial Roads and Highways (ARH)	Collector and Local Roads (CLR)	Underutilized and Surface Parking Lots (USPL)	Natural Corridors (NC)
Regulation Services	Air Quality Control	(Air Filtering) - (1) Trees in canyons, reduce airflow (Pugh et al., 2012; Säumel et al., 2016) + (2) Green walls, green roofs, vertical greens, increase surface area (Morakinyo et al., 2016) + (3) vegetation barriers function as shields near high traffic areas (Säumel et al., 2016) - (4) Green walls near highways, confine pollutants - (5) Green walls near high-rise buildings, confine particles (Abhejit et al., 2017) (Causing allergic reaction and pollution) - (8) Some pollinating species through intoxication, VOCs emission, BVOCs emission, and reducing air dispersal (Lyytimäki & Sipilä, 2009; Roman et al., 2021)		(Causing allergic reaction and pollution) - (6)Some pollinating species through intoxication and VOCs emission (J Ahern, 2016; Lyytimäki & Sipilä, 2009) - (7) Spontaneous, ruderal, and wild-grown vegetation on vacant and abandoned lands are a source of pollen and can increase Ozone (Alizadehtazi et al., 2020)	
		(Air Filtering) - (9) Trees near high traffic areas reduce air dispersion and trap pollutants increasing pedestrian exposure to harmful pollutants + (10) Trees and urban forests can create distance between cars and pedestrians and act as a barrier that limit pollutant to disperse into pedestrian domains (Nowak et al., 2018)			
		(Balancing CO2/O2) + (11) Trees, green walls, and green roofs still provide fresh air in the case that traffic is removed (Pugh et al., 2012) + (12) Carbon sequestration by vegetation and plants (Escobedo et al., 2011) + (13) Vegetated areas and underground parking produce by evenly distribution - (14) Maintenance of vegetation emit Carbon and other Green House Gasses - (15) Urban trees become carbon neutral only after ~three decades (Roman et al., 2021)			
				(Balancing CO2/O2) + (16) Lesser managed trees are better carbon pools than managed street trees (Strohbach & Haase, 2012)	
	Water Regulation	(Reducing surface runoff) + (17) Street trees are more effective in retaining runoff than grass surfaces in highly built-up areas (Lindberg et al., 2018)	(Drainage Revitalization) + (18) Porous pavements produce in low and medium traffic roads offer retention, infiltration and reservoirs for irrigation (Sprouse et al., 2020)	(Drainage Revitalization) - (19) Bare soils in contaminated lands Accumulate pollutants and contaminate the groundwater (Alizadehtazi et al., 2020; C. A. De Sousa & Spiess, 2018)	(Drainage Revitalization) + (20) Urban forests infiltrate rainfall on-site (Escobedo et al., 2011) - (21) Urban parks need excessive volumes of water for irrigation (J Ahern, 2016)
		(Treating urban runoff) + (22) Vegetation in LID measures including bioretention ponds reduce nutrient and heavy metals from stormwater runoff (Panagopoulos, 2019)		+ (23) Vegetated areas including Bioswales and bioretention facilities reduce volumes of urban runoff on underutilized lands (Christman et al., 2018; Sansalone et al., 2013)	(Treating urban runoff) + (24) Riparian zones,)ghting, and de-channelization of urban creeks improve the water quality (Krauze & Wagner, 2019)
		(Drainage Revitalization)			

+ (25) Distribution of LID measures along streets significantly reduce runoff volume with respect to centralized LIDs (Krauze & Wagner, 2019)

(Treating urban runoff/graywater)
+ (26) Pervious pavements alongside roads can capture suspended solids as well as retaining runoff pollutants (Sprouse et al., 2020)
+ (27) Greenwalls can be used to treat kitchen wastewater (Dal Ferro et al., 2021)

(Erosion Control)
+ (28) Natural land covers and soils reduce erosion risk (Escobedo et al., 2019)

(Erosion Control)
+ (29) Vegetated surfaces bind the soil particles and reduce the sediment production (Alizadehtazi et al., 2020; Mexia et al., 2018)

(Evapotranspiration)
+ (30) GI elements with vegetation produce this service
+ (31) Sunlight vegetation and trees in high density environments produce more evapotranspiration than shaded counterparts (Zölch et al., 2016)

Noise Reduction

(Noise Absorption)
+ (32) Green roofs, trees, green walls, and porous pavements, when placed near motorized traffic (Berardi et al., 2014; Ramyar et al., 2020)
- (33) Addition of water sounds to high traffic roads makes unbearable environments (Hong & Jeon, 2013)

(Noise Absorption)
+ (34) Pervious pavements on low and medium traffic areas reduce ambient noise (Liu et al., 2016)
+ (35) Porous asphalt reduces the automobile traffic noise by more than half (Sprouse et al., 2020)

(Noise Generation)
- (36) Birds are source of noise and wake up residents early (Belaire et al., 2015; Cox et al., 2018)
+ (37) Bird noise makes traffic noise more bearable along the roads (Hong & Jeon, 2013)

Climate Regulation

(Temperature reduction by shading)
+ (38) Trees on impervious environments reduce stored heat (Saaroni et al., 2018; Yafei Wang et al., 2014; Yupeng Wang et al., 2016)
- (39) Continuous tree canopies or an array of similar tree species trap heat (Norton et al., 2015)
- (40) Evergreen trees in cold regions reduce sun exposure during the winter (Erker & Townsend, 2019)
- (41) Green roofs and green walls have miniscule cooling effect at the street level because they have no shading (Zölch et al., 2016)

(Temperature reduction by shading)
+ (42) Trees and dense vegetation in green spaces reduce surface temperature better than scattered coverage (Puppim de Oliveira et al., 2022)
+ (43) Tree shades alongside water bodies reduce their temperature (Wu & Zhang, 2019)

(Temperature reduction by evapotranspiration)
+ (44) Short vegetation cover is cooler surface coverage than concrete and soil due to evapotranspiration (Säumel et al., 2016)
+ (45) Evapotranspiration from trees on roads is more effective than trees in nearby parks (Gunawardena et al., 2017)

(Temperature reduction due to air exchange)
- (46) Dense tree stands reduce air exchange (Abhijith et al., 2017; Säumel et al., 2016)
- (47) Trees with continuous canopy in urban canyons trap the summer heat (Norton et al., 2015)

(Temperature reduction due to shortwave diffusion)
+ (48) Open spaces have higher moisture and diffuse shortwave radiation (Lindberg et al., 2018)

Cultural Services

(Co-inhabitation of Wild animals)
+ (49) Birds are source of personal pleasure (Belaire et al., 2015)
- (50) birds droppings on cars (Belaire et al., 2015)
- (51) Birds causing disturbance and generating dirt (Belaire et al., 2015)

Aesthetic

+ (52) Street trees and small plants behave as pedestrian facilities

- (54) Too dense or too dark vegetation structures (Säumel et al., 2016)

(Reconnecting to the nature)
+ (55) Wilderness sites create emotional attachment of urban dwellers (Kowarik, 2021)

(Ornamental uses)

- (53) monotonous greenery that obstruct more than 60% of view act as continuous façade (Ewing et al., 2016)

- (56) Vegetation in vacant lands are perceived as unattractive when unmanaged (J Ahern, 2016)

+ (57) Accessible monumental trees, rivers, and streams attract pedestrians and tourists (Ronchi et al., 2020)
+ (58) Increased property value for nearby properties of urban forests (Escobedo et al., 2011)
(Reconnecting to the nature)
- (59) Tall trees with large canopies in parks and natural areas can block good views (Potgieter et al., 2019)

(Creating nuisance)
- (60) Leaf, branch , and fruit litter from trees causes public annoyance (Roman et al., 2021)
- (61) Too dense or too dark vegetation structures (Säumel et al., 2016)
- (62) Infrastructure damage due to routes and microbial activities (Alizadehtazi et al., 2020)
- (63) Trees surrounded by impervious surfaces or mulch are more prone to scale insect infection than those surrounded by other plant species (Gardiner et al., 2013)

(Creating nuisance)
+ (64) Divers and complex structures of plant species decreases the severity of pest outbreaks due to supporting habitat for predator species (Gardiner et al., 2013)
- (65) Non-native tree species colonizing river corridors, wetlands, and vacant lands reduce sense of place and aesthetic values (Potgieter et al., 2019)

(Creating nuisance and ornamental use)
- (66) Ornamental vegetation are usually non-native which increase pest population (Gardiner et al., 2013)

(Creating nuisance)
+ (67) Riparian zones, daylighting, and de-channelization of urban creeks reduce waterborne diseases (Krauze & Wagner, 2019)

(Increasing property value)
+ (68) Increased property value near urban trees as an indirect manifestation of aesthetic benefits (Roman et al., 2021)
- (69) Gentrification as a consequence of tree planting (Long & Rice, 2019; Silva et al., 2018)

(Cultural Heritage use)
+ (70) Adding more natural assets in urban areas makes these spaces enjoyed as cultural and historic heritage (Ronchi et al., 2020)

(Cultural Heritage use)
+ (71) Maintenance of historical landscape and cultural species is highly valued by societies (Millennium Ecosystem Assessment, 2005)

(Exposure Discomfort Reduction)
+ (72) Leafy GI elements provide gradients of shading (Tamminga et al., 2020)
+ (73) Birds control the population of pests and rodents (Belaire et al., 2015)
+ (74) Vegetation reduce radiation and reflection of solar and long wave radiation from sealed surfaces (Säumel et al., 2016)

(Stimulating recreation use)
+ (75) Adding trees to urban roads improve quality of streetscapes (Säumel et al., 2016)

(Increase Livability)
+ (76) Introduction of measures such as sustainable urban drainage systems, flower gardens, and green roofs make these places more usable (Maes & Jacobs, 2017)
- (77) Sites that are neglected, abused, and damaged make
Unpleasant pedestrian environment (Plieninger et al., 2013)

(Stimulating recreation use)
+ (78) Urban greenery provide venues for passive recreation after COVID-19 pandemic (Hui & Jim, 2022)
+ (79) Urban forests promote exercise, cultural events, wild life viewing activities (Escobedo et al., 2011)
+ (80) Active uses such as public parks generate pedestrian traffic (Ewing et al., 2016)
- (82) Inactive uses such as blank walls, surface parking lots, vacant lands reduce pedestrian traffic (Ewing et al., 2016)
- (83) long distance from home to park entrance and low number of crosswalks likelihood and frequency of physical activity in parks (Lee et al., 2015)

(Exposure Discomfort Reduction)
+ (81) Trees and greenwalls when placed in heat hotspots of compact midrise development significantly reduce pedestrian heat stress (Zölch et al., 2016)

(Stimulating recreation use)
- (84) Overgrown vegetated areas and trees reduce passage for pedestrians (Roman et al., 2021; Säumel et al., 2016)

(Stimulating recreation use)
+ (85) Small, inexpensive, and temporary interventions such as repurposed railways and shallow water shores transfers vacant lands to

(Excessive availability)
- (87) Too many paths discourage going to a park (Tandarić et al., 2020)

			promenades for local residents (Unt & Bell, 2014) - (86) Inactive uses such as blank walls, surface parking lots, vacant lands reduce pedestrian traffic (Ewing et al., 2016)	- (88) Too many animals of the same species create nuisance (Tandarić et al., 2020)
Information for cognitive development	(Sense of Safety) - (89) Covered, non-visible sites and places without proper lighting deemed unsafe (Plieninger et al., 2013) + (90) Tree canopy cover in public spaces reduce crime (McPhearson et al., 2016) + (91) Street verge plants and trees create a refuge for pedestrians by functioning as buffers between car traffic and pedestrian environment (Beery et al., 2017) - (92) Property and utility damage during weather events caused by tall trees (Roman et al., 2021) (promoting Environmental Education) + (101) Exposure to wild-grown species and lesser managed vegetation alongside roads may elevate their acceptance (Kowarik, 2018; KOWARIK, 2021; Kowarik et al., 2021) + (102) Due to the number of pedestrians, street verges provide ample opportunities for education about biodiversity and wild-grown species + (103) Guerrilla gardening promote experience with natural elements (Säumel et al., 2016)	(Sense of Safety) - (93) Covered, non-visible sites and places without proper lighting deemed unsafe (Plieninger et al., 2013) + (94) Tree canopy cover in public spaces reduce crime (McPhearson et al., 2016) - (95) Unmanaged vegetation seen as a trace of neglect (Säumel et al., 2016)	(Sense of Safety) + (96) incorporation of GI elements in vacant lands may reduce gun violence (Lee et al., 2015) - (97) Sites that are dangerous or threatening due to unmaintained landscaping (Plieninger et al., 2013) - (98) Reduced view by spontaneous vegetation (Säumel et al., 2016)	(Sense of Safety) + (99) Natural land covers and urban forests attenuate tidal waves, reduce flood risk, and attenuate hurricanes (Escobedo et al., 2011) - (100) Dense vegetated areas in parks create distinctive rooms and cause feeling of threat (Dumitru et al., 2020)

As the objective of this dissertation is blending GI and intensification planning, this section focused on developing design tools that can integrate GI and pedestrian connectivity. Two tabular urban design tools were developed to integrate GI elements in the UPOSs classified earlier in this chapter. These tools were intended to address the identified urban planning/design gaps in the previous section. The first developed tool comprised of a GI typology based on the structural properties of the GI elements and an emphasis on their multifunctionality. The second tool prioritized the needed ecosystem services in each UPOSs. It also listed the physical interactions between the GI elements and the surrounding grey infrastructure that led to ecosystem services or disservices. In the following section, the tabular tools are utilized to develop a proof-of-concept urban design for the enhancement of GI and pedestrian connectivity in areas under intensification. The exemplar design proposal contains all the UPOSs and serves as design guidelines for integrating GI and pedestrian networks.

4.9 Design Proposal- The Restoration of Mary Fix Creek in Mississauga Centre

In this section, a design proposal that applies the two tables from the previous section is presented. Eight design proposals for a collection of eighth sites in the case study areas were developed. After comparing the proposals, a greenfield site in Downtown Mississauga was chosen to be presented in detail in this chapter because this site includes all the four identified UPOSs and uses a wider an array of GI elements and ecosystem services presented in Table 4-2 and Table 4-3. This example serves as a comprehensive overview of the proposed tools in developing an integrated GI and pedestrian network.

4.9.1 Site Description

The selected site, shown in Figure 4-12, is a large greenfield lot (~8.2 Ha) located to the west end of Downtown Mississauga. The site is vacant land, under the category of ULs, which is surrounded by ARHs, CLRs, and NCs. It is bounded by a high traffic, seven-lane arterial (Burnhamthorpe Rd) to the northwest and two four-lane CLRs to the northeast and east (Confederation Parkway and Webb Dr, respectively). There are also portions of Mary Fix Creek in the neighbouring sites. Finally, there is a surface parking area in the northeast of the site. From a GI perspective, Mary Fix creek, which is a significant natural asset of Downtown Mississauga is unfortunately piped and buried under this site. Regarding pedestrian connectivity, this site is entirely fenced with no internal intersections for pedestrian access (City of Mississauga, 2010; Google, 2023).



Figure 4-12 The site in Downtown Mississauga used for the design proposal

The city of Mississauga has envisioned a type of project for this site that benefits both GI and pedestrians. Table 4-4 includes examples of responses from the interviewees that are specific to this site. For example, one respondent answered a question about the GI development in Downtown Mississauga by pointing out their efforts along the Mary Fix creek portion to reduce flooding downstream by daylighting the creek, which includes a greenway along the creek. Another interviewee responded to a question about the pedestrian environment in the centre by talking about their plans to break down urban-block sizes to make them more human-scaled and pedestrian friendly (Mississauga Interviewee #5).

Table 4-4 Collecting data about the site from the interviews

Question type	Question example	Response example (Specific to Mary Fix Creek Area)
Broad questions	What are and how the natural features of the centre have been modified over time?	"*Cooksville Creek and Mary Fix Creek, …they have been affected a lot across the city. Some creeks have been channelized whereas most have been piped and enclosed*".

open ended questions	How can we define environmental dimensions of the center?	"*We have not yet developed quantitative measuring tools, but e-Maps aerials may provide some insight on coverage (green, heat island, carbon footprint)*".
GI specific questions	Have there been decisions promoting green infrastructures in the centre?	"*Along Mary Fix Creek, particularly within the Downtown Core, the City have implemented a strategy to mitigate continuous flooding issues down the stream*".
Pedestrian environment questions	What are you trying to do for creating a pleasant pedestrian environment? Why hasn't it been done before? What were the obstacles?	"*We have these large super-blocks. We tried to break them down into a fine grid of streets where we can and where feasible to encourage more walkability, more permeability, to help with the scale and access to build form and development pedestrian friendly, we have also a layer of parks and open space infused within this. We have to be really creative about the open space, not in the traditional form, but in ways of doing that through amenity spaces which we now other cities have started to be very innovative about*"

Mary Fix Creek starts from northwest of Downtown Mississauga, runs along the southwest side of the center and merges into the Credit River in Port Credit before discharging into Lake Ontario. Mary Fix Creek plays a critical role in flood management and soil erosion prevention in south Mississauga and has been undergoing extensive restoration. The daylighting and revitalization of Mary Fix Creek is a significant component of the Hazel McCallion Line (Hurontario LRT) project, led by Metrolinx. The city and Credit Valley Conservation are collaborating with Metrolinx to ensure the environmental sustainability of the project (Metrolinx, 2024).

The project covers a stretch of Mary Fix Creek from Old River Road to the Credit River, which includes widening and deepening the creek bed to handle large-scale floods (up to a 100-year flood event) and installing new concrete flood channels. The revitalization has also contained removing invasive plant species and replanting native vegetation to restore local biodiversity. These modifications are aimed to enhance flood protection for the surrounding communities, particularly in areas near Port Credit GO Station. The creek revitalization is part of broader efforts to future-proof the area against climate-related flood risks while supporting local wildlife and creating green spaces. This work primarily focuses on the areas near Hurontario Street and Port Credit but does not extend upstream and into Downtown Mississauga (Metrolinx, 2024).

Downtown Mississauga, due to its sealed surface and its volume of urban runoff, significantly contributes to the flooding and erosion risk of the downstream of Mary Fix creek. The piped section of the creek under this site provides an opportunity for a restoration intervention and urban runoff management at its source through the presented design proposal. The proposed design aims to reduce the flooding and erosion risk as well as the need for further expansions of the Metrolinx projects in the future.

This design proposal is not an ecological restoration plan, as further ecological restoration plans should be developed in the next steps by consultation with ecologists, environmental planners, and landscape architects. Before going to the ecological restoration phase, recognizing the needed ecosystem services, and defining spaces for the interventions that can provide these services are required. Accordingly, the design proposal identifies where the daylighting is needed and how its interaction with the surrounding built environment provides ecosystem services and avoid disservices.

The site was visited to study its accessibility, quality of GI elements, pedestrian environment, and encouragement of active transportation. A few photos of the site are shown in Figure 4-13. The site has been mowed regularly. Therefore, wild grown species are not present except for a few trees and shrubs. The Mary Fix Creek portion is daylighted on the neighbouring lots and this site creates a sharp discontinuity in the Creek's natural corridor. The site is entirely blocked from pedestrian access. The pedestrian environment includes sidewalks that are next to streets with high-speed and high-volume traffic. There is a lack of barriers to separate pedestrian environment from the road. Although impervious sidewalks are well maintained, no pedestrian amenities such as benches are present. The block size is quite large, with each side spanning roughly 500 meters without any crosswalks. There are no

intersections to take an alternative route, but there are pathways along the Creek on the other sides of the roads, which has the potential to be connected to the site, including a greenway on the north of the site and a park on the south (Google, 2023).

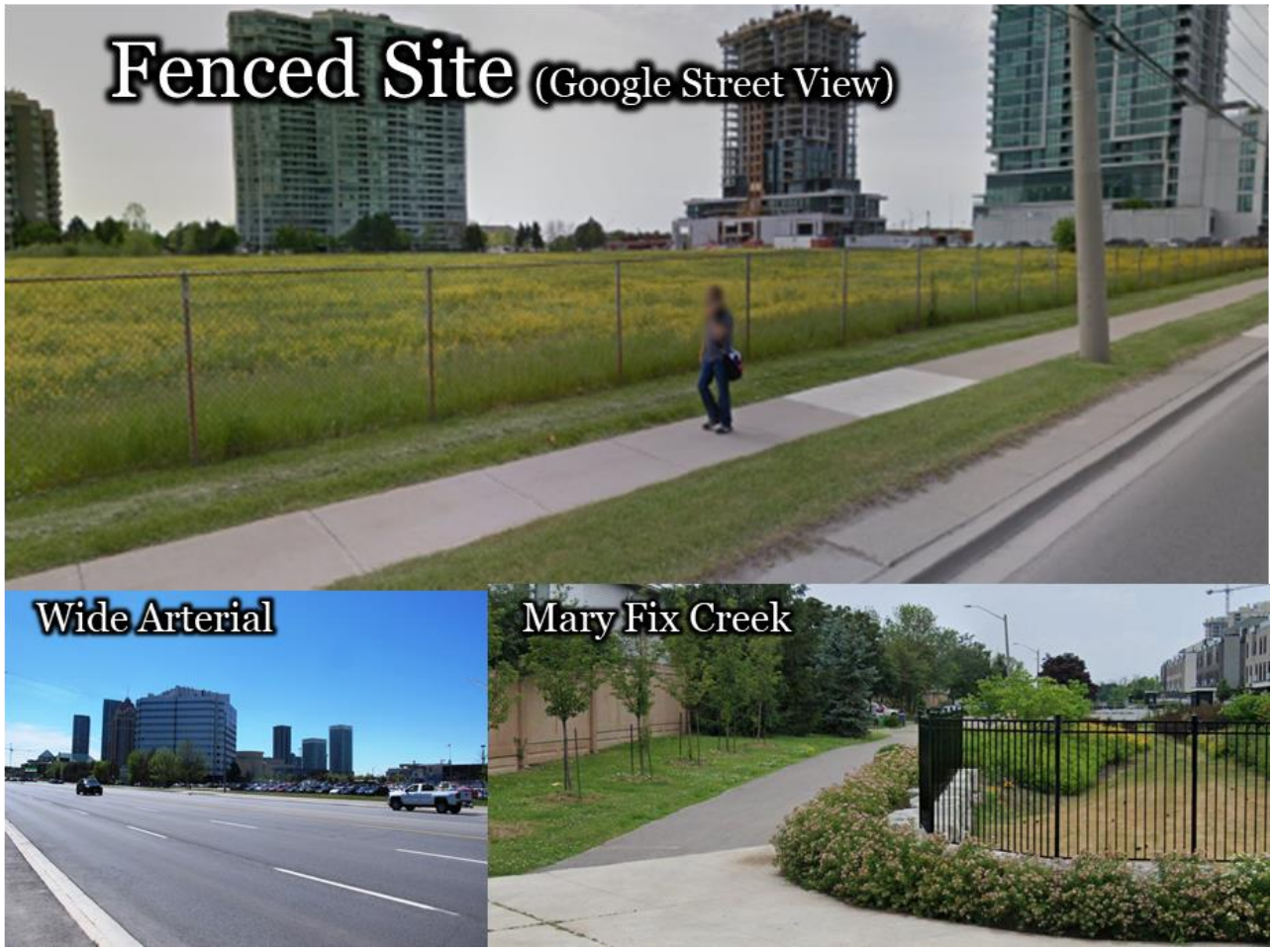


Figure 4-13 Example photos collected during the virtual and in-person site visits.

Figure 4-14 compares the proposed development by Downtown21 master plan and the developers' plan. Downtown21 proposes a daylighting project for the piped creek to connect the existing greenway and park on the neighbouring sites. Moreover, the masterplan proposes a continuous green space for the daylighting of the creek besides traffic calming measures on the south are planned for pedestrian connectivity. However, in the current developer's plan, the area for daylighting is discarded, the

development foresees no connection with the neighbourhood, an east-west road fragments the green space, and the traffic calming measures on the south are discarded. These interventions from the masterplan and their contradiction with the developer's proposal are highlighted in Figure 4-14. Note that both masterplan and developer's plan include additional local roads and multiple buildings with openings, which provide a pedestrian environment (City of Mississauga, 2010; M-CityCondos, 2023).



Figure 4-14 Comparison between the masterplan (top) and developers' plans (bottom) (www.mcitycondos.com)

4.9.2 Needed Ecosystem Services

The following ecosystem services are needed in this site. Drainage revitalization and erosion control are needed due to the Mary Fix creek's piped condition. Moreover, the urban runoff from the future development on this site needs to be regulated on site to avoid discharge of excessive urban runoff to the daylight section of the creek. Climate regulation is essential in this site because of the 60m wide arterial road and its dark and impervious asphalt land cover. Noise reduction and air filtration are also needed along the ARHs and CLRs due to the volume and speed of traffic. Finally, safety and attractiveness of

pedestrian environment along the ARH and CLRs are needed to promote walking and other types of active transportation (Mississauga Interviewee #5; Google, 2023). Moreover, Educational ecosystem services are needed to increase public awareness, acknowledge the underrepresentation of Indigenous perspectives, share the history of local indigenous communities, and their relationship with the land.

4.9.3 Design Strategies

Several design strategies are followed to provide the identified ecosystem services by incorporating GI elements that are suitable for each UPOSs. For example, vertical greens are proposed in the ARHs to reduce noise pollution and improve air filtration. They also separate pedestrians from traffic to improve pedestrian's perception of safety and contribute to aesthetics of the sidewalks by masking the road. Within the site, for GI connectivity, individual GI elements are arranged in continuous corridors along ARHs, and in steppingstone configuration along CLRs as CLRs are interrupted by the individual properties. To effectively connect Table 4-2and Table 4-3 with the proposed design, each intervention is accompanied by codes in parentheses. The initial two codes correspond to the GI elements and UPOSs detailed in GI Typology Table 4-2. The third code refers to the ecosystem services or disservices listed in Table 4-3. It is important to note that when a term is linked to multiple references within the tables, a comma is used for these references. For instance, if a riparian zone is anticipated to provide several ecosystem services while mitigating disservices, this is denoted as (11-d-24,28,29,67).

The following interventions are proposed to enhance the cultural representation of Indigenous history and integrate Traditional Ecological Knowledge (TEK) into the site design. For the Mary Fix Creek restoration, interpretive pathways are introduced, featuring Indigenous artwork and plaques that detail the creek's historical and ecological significance to local Indigenous peoples. This initiative is paired with naturalization techniques inspired by TEK, such as planting native trees and shrubs recognized for their traditional medicinal and food uses (Simpson, 2008; Kimmerer, 2013; Hill, 2012).

To further incorporate Indigenous values into the design of GI and pedestrian networks, symbolic elements, such as mosaic artworks and water features with patterns inspired by Indigenous iconography, are proposed for public spaces. Pedestrian routes host plaques and interactive displays sharing the stories and relationships of local Indigenous communities with the land. Additionally, native vegetation such as milkweed and cedar, which hold ecological and cultural significance, are planted along the creek to align GI connectivity with an Indigenous lens (Turner, 2005). Cultural markers, including installations and

signage, are added to acknowledge the historical presence and ongoing contributions of the Mississaugas of the Credit First Nation (Indigenous and Northern Affairs Canada, 2013). Educational outreach initiatives are developed in partnership with local Indigenous communities to foster understanding of the creek's biodiversity and cultural relevance (Kimmerer, 2013).

4.9.4 Proposed Structures

The proposed designs are presented in subsequent figures. In each figure, the interventions are numbered and are accompanied by a descriptive legend. The proposal includes structures, such as new buildings with openings, a high-quality park, a daylight section of the creek, and integrated corridors of GI and pedestrians. The proposed structures are depicted in Figure 4-15. Note that for enhancing connectivity, the integrated corridors are extended beyond the site to connect with existing green spaces of the neighbourhood. Further description for each intervention is as follows:

1. There are two-row configuration of buildings with no high-rise to the south to avoid sunlight block. The target density of development is kept the same as prescribed in the downtown21 plan of Downtown Mississauga. While the masterplan achieves the densities using high-density mid-rise, which does not allow space for an internal park and the developer plan is developing 10 high-rise buildings, this design proposal introduces the low-rise development on the south side and the high-rise development on the north row.
2. The openings are provided for both pedestrian access to the park and car access to the buildings (8-a,b).
3. Instead of the east-west road in the master plan and the developer’s plan, a high-quality park (20-d-11,12,13,20,79,80,etc.) is placed between the buildings with multi-functional facilities, such as water plazas and the compact and diverse range of native species to both attract pedestrians and contribute to biodiversity (20-c-23, 20-d-16).
4. Daylighting section is provided by digging the pipes out and providing the riparian zone beside the creek (11-d-24,28,29,67). This section is continuously connected with the high-quality park.
5. The integrated pedestrian and GI corridor is discussed in detail in Figure 4-16.

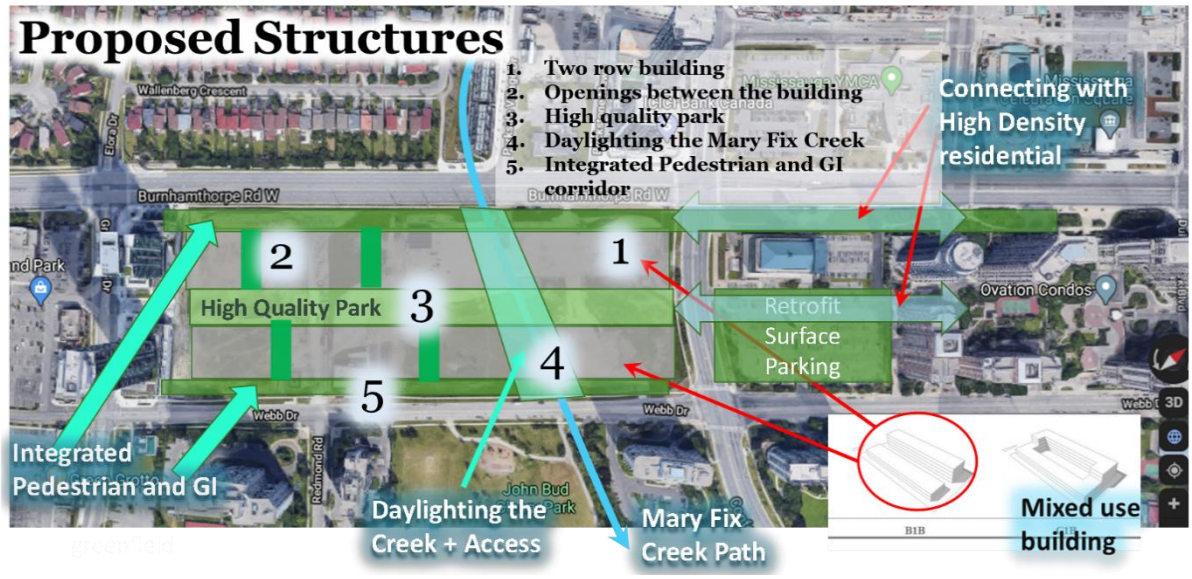


Figure 4-15 The proposed structures and its connectivity with the surrounding neighbourhood.

4.9.5 Proposed Corridors

In addition to the central park, two integrated corridors are proposed as shown in Figure 4-16, along Burnhamthorpe Rd. and Webb Dr. These corridors are formed by a ~1m wide vertical green on the side of arterial road (2-a), which should be at least 8m (2-a-2,3,4,5) apart from the sidewalk for the effective air filtration (Morakinyo & Lam, 2016). This 8m gap is filled by longitudinal (16-a) and low-profile (12,14,15-a) GI structures. It can also include GI elements, such as bioswales and xeriscaping. This is followed by a wide sidewalk, close to the buildings. The corridor along the CLR of Webb Dr is formed by 1.5m to 3m wide sidewalks close to the building and a 2m wide vegetated area covered by trees and shrubs (3-b) (13,15-b). This corridor is located alongside a 26m collector road, which has significantly lower traffic. Hence, the air pollution and noise pollution are less problematic while climate regulation (balancing CO2/O2) (3-b-16) and environmental factors of the pedestrian network are needed (15-b-44,46,47,54,61). The trees and shrubs both improve evapotranspiration and serve as pedestrian features. These corridors are connected using a trail along the creek and pedestrian paths passing between the buildings and the park (18-b,d) (9-b).

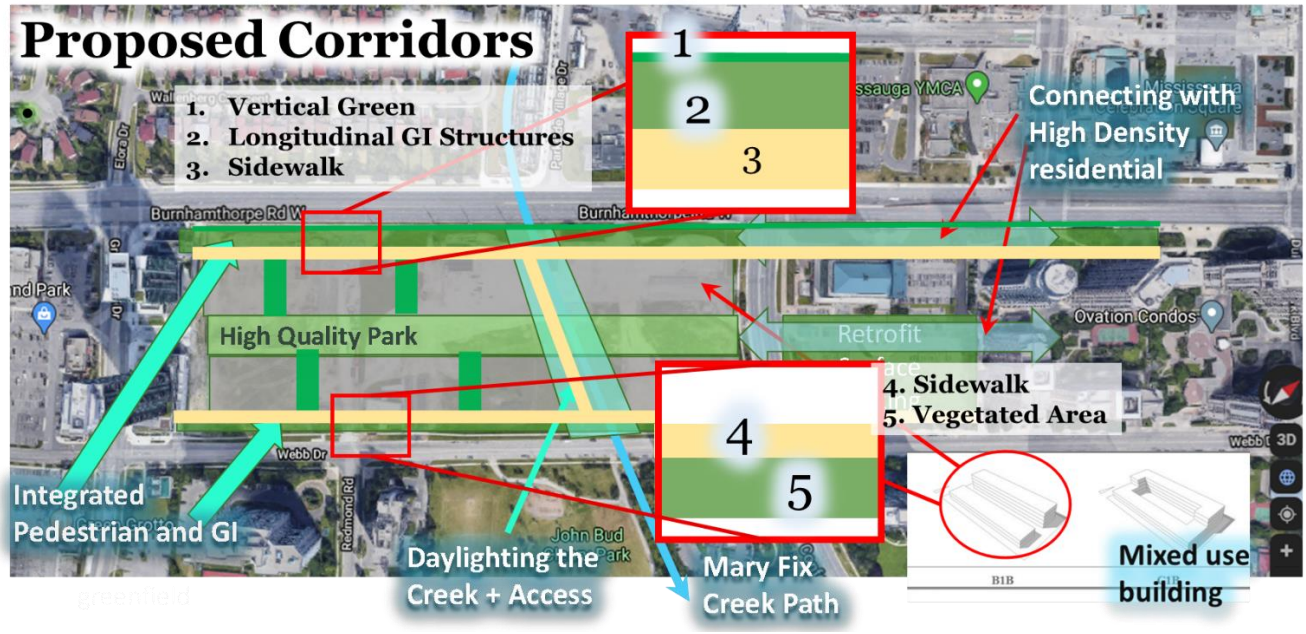


Figure 4-16 Detailed view of the two proposed corridors.

4.9.6 Proposed Ecosystem Services and Avoided Disservices

In Figure 4-17, a range of needed ecosystem services and avoided ecosystem disservices are highlighted based on the types of UPOSs. The interventions for the UPOSs of each number on the figure are described as follows:

1. The corridor along the arterial road is intended to enhance both GI and pedestrian environment. It reduces the air pollution by air filtration from the vertical green. It also deals with the stormwater of the arterial road through bioswales proposed adjacent to the roadway (12,16-a-22,25). Moreover, the design improves temperature regulation by evapotranspiration from vegetation (12,16-a-30). Note that trees are not used to prevent pollutants from accumulating near sidewalks (3-a-9). For traffic safety, the sidewalk is separated from the street by vertical greens (2,3-a-89,90,91). For crime safety, low-profile GI structures are preferred because too dense vegetation cover in addition to the vertical greens can create crime fear (14,15-a_84,89). In addition, this corridor holds street furniture and public art for cultural ecosystem services (14,15-a-52).
2. The corridor along the local road is intended to improve air quality and cultural ecosystem services. They balance CO2/O2 and contribute to climate regulation and biodiversity (3-b-

11,12,13). This corridor is formed by sidewalks, trees and a layer of understory covered by native shrubs and hedges, which has cultural value and increase environmental engagement (15-b-44,45,75,101,102,103). In addition, this corridor has a wider intersection with the Creek corridor than the ARH to facilitate better connection with the internal park and the existing park on the other side of the road.

3. The opening spaces are covered with pervious pavements. They provide venues for temporary GI elements and installations, such as modular structures, which enhance both GI connectivity and physical environmental features for pedestrian connectivity (9-a,b-18,25,26,32).
4. The NC for the daylighting of the Mary Fix is intended to address water regulation while providing cultural ecosystem services. The daylighting of the creek provides habitat and restores riparian zones, which revitalizes soil infiltration and reduces flooding and erosion (11-d-20-24,28,29,43). It also enhances cultural ecosystem services by providing attractive amenity spaces along the creek (11-d-55,57,67,71,78,79,80,99).
5. In ARHs, to avoid disservices, trees are not placed alongside the arterial to avoid the obstruction of airflow (3-a-1,9) (Abhijith et al., 2017; Pugh et al., 2012). Instead, vertical greens or densely packed shrubs can separate this high traffic road from the sidewalk. Moreover, low-cost and impermeable structures, such as metal or plastic barriers between the road and the vertical greens can further reduce the pollutant depositions regardless of the wind speed and density of the vegetation (2-a-2,3) (Hashad et al., 2020). Moreover, green walls on high-rise buildings that face speed traffic must be avoided because they concentrate the pollutants and degrade air quality. Therefore, only the internal façade of the buildings, which are exposed to the internal park, are covered by green walls (1-a,b,c-4,5) (Yafei Wang et al., 2014).

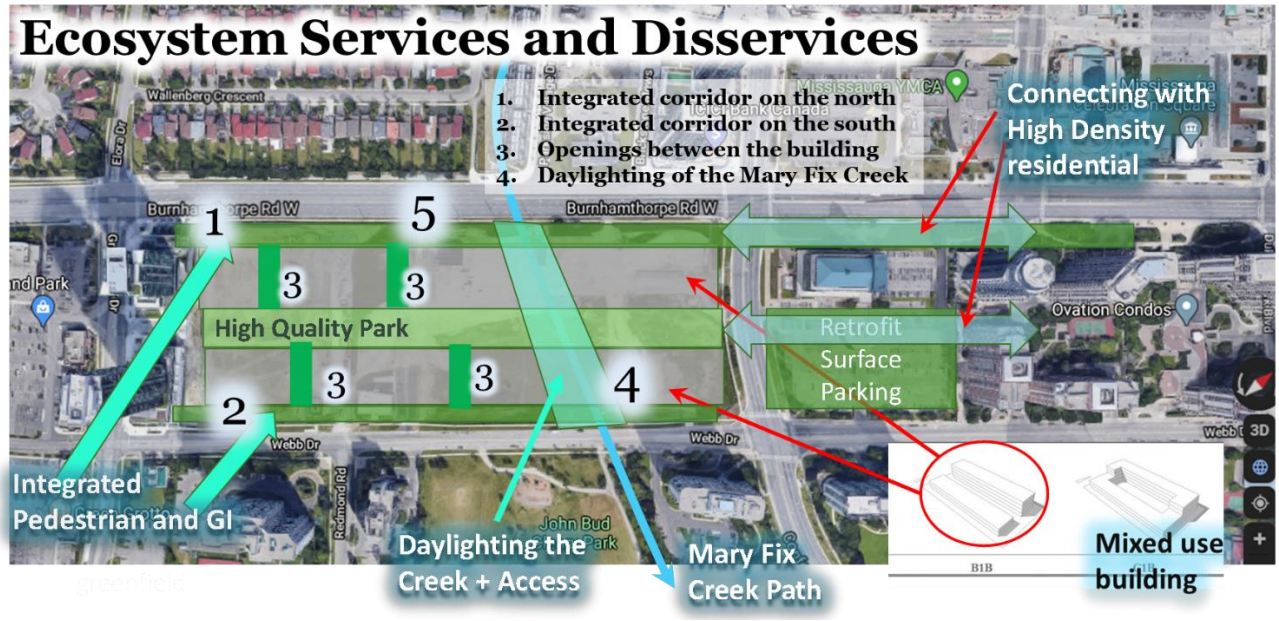


Figure 4-17 the need for delivering ecosystem services and avoid disservices

4.9.7 Proposed GI and Pedestrian Connectivity

The proposed design includes interventions to create the connectivity between proposed features of GI and pedestrian networks and the adjacent neighbourhood. These interventions, which are highlighted in Figure 4-18, are described as follows:

1. Narrowed roads with crosswalks connect the daylight section of the Mary Fix creek with the greenway across the arterial road and with John Bud Park across the local road. The reduced distance between the daylight section and these neighbourhood features improves the functionality of steppingstone configurations of GI.
2. The opening spaces (8-a,b) between the buildings act as intersections and provide alternative paths for both pedestrians and GI steppingstones, which connect the integrated corridor of GI and pedestrian networks with the high-quality park.
3. The NC along Mary Fix creek connects the high-quality park (20,18-d) with the integrated corridor of GI and pedestrian networks. The extension of the integrated corridor of GI and pedestrian networks along the arterial road extends the pedestrian connectivity of the site with the high-density development along the arterial road.

4. Retrofitting the surface parking area to the northeast as an UL creates a GI steppingstone connection with the high-quality park. It also improves the connectivity between high quality park and the green spaces in the residential development on the other side of the retrofitted parking.

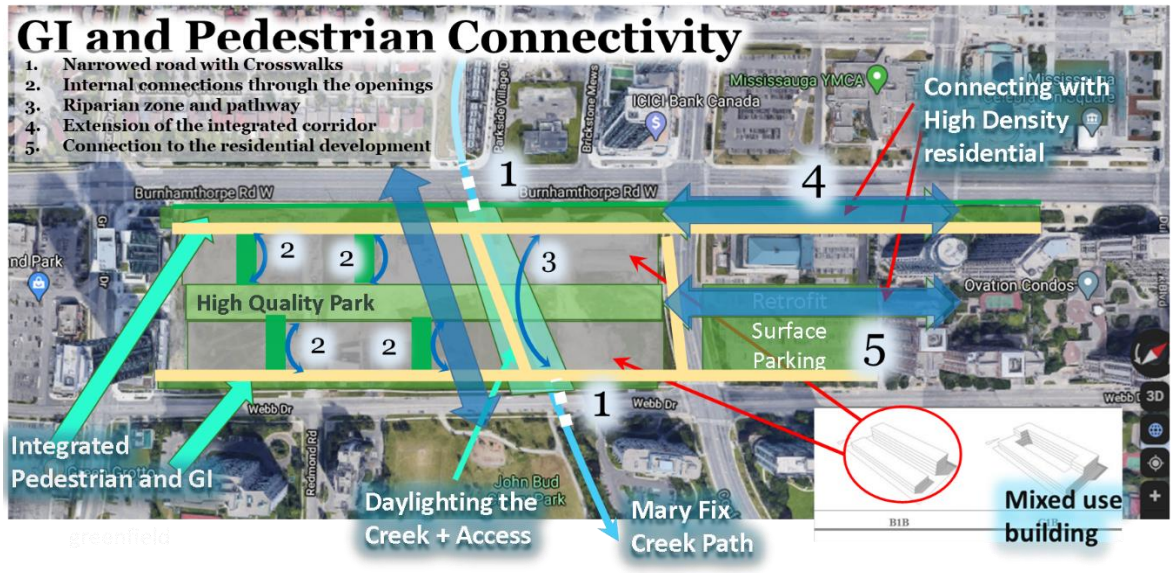


Figure 4-18 Connectivity for the proposed GI and pedestrian networks.

4.10 Exploring the Transferability of the Proposed Method

The proposed guidelines that define the interaction between GI elements and the built environment components of dense urban areas are based on the structures of GI elements and are independent from local variables, such as water tables and soil type. These GI structures are suitable for medium-sized UGCs since the design strategies in this research have been proposed for two medium-sized UGCs. For universally applying these strategies to any intensified urban cores, the density target (200 jobs/residents per hectare), and the size of UGCs determine needed ecosystem services as well as available UPOSs for integrating GI and pedestrian connectivity. Accordingly, GI measures are selected from the tabular design tools based on the needed ecosystem services and the available UPOSs in any dense urban environments. Note that the

scope of this research is limited to UGCs and urban cores such as Thunder Bay, ON, are outside the scope of this research.

For larger and smaller UGCs, further research is suggested to identify proper UPOSs as well as the needed ecosystem services. Regarding UPOSs, for example, there are little to no vacant lands available in high density urban areas, such as downtown Toronto with the density target of 400 jobs and residents per hectare. In smaller UGCs, such as Downtown Cambridge, and Downtown Guelph with 150 jobs and residents per hectare, there are significantly more opportunities for re-development and retrofitting projects. For needed ecosystem services, enhancing air quality, and addressing heat island effect, for instance, are required in high density centres while these services are significantly less needed in lower density centres. Accordingly, new research should be conducted to address these differences in other density targets.

4.11 Conclusion and Future Work

This study improves the traditional role of urban design from developing site-scale interventions to enhancing GI and intensification models. GI site-scale designs without considering the higher-scale interactions with other urban infrastructures, surrounding environment and urban residents fail to guide the transformation of urban areas under intensification. There is a need for multiple-neighborhood and city-centre scale designs to link individual sites, form an urban landscape, and address the objectives of both GI and intensification planning. As many of these urban areas have preliminarily encountered intensification strategies, GI can be planned to be integrated as a new component. This study addresses the integration of GI and intensification by focusing on the potentials of creating a connected network of GI and pedestrian corridors. This approach is applicable to the metropolitan scale planning and design and supports the enhancement of connectivity in urban areas.

Through the lens of urban networks, this chapter looked at GI networks, which facilitate the distribution of ecosystem services, and intensification networks, which facilitate pedestrian movement. It focused on integrating these two networks in shared UPOSs, where they are co-occurred due to space constraint in areas under intensification. The proposed design tools envision high-quality GI as “breathing room” for intensified urban areas to assist shaping resilient cities in the era of climate uncertainty, resource scarcity and population growth. However, the proposed design-based strategies of this study are a portion of a

larger picture of smart growth in Southern Ontario and is incapable of serving as ultimate environmental solutions. Design tools in intensification planning need to be constantly supplied with the local technical data and require further urban studies, such as the transition of GI and other urban networks from city centres into broader landscapes, and the integration of other active modes of transportation, such as cycling.

Chapter 5
Conclusion

This dissertation focused on addressing the question of how intensification and GI can be integrated through urban design. This research attempted to identify the contribution of GI to intensification goals through the provision of ecosystem services. In addition, it sought to identify opportunities for GI development through intensification processes. There was a focus on promoting GI connectivity and pedestrian connectivity for creating a built environment that is suitable for both GI planning and intensification planning. Accordingly, this dissertation proposed an integrated network of GI and pedestrian routes since both GI and pedestrian connectivity are developed in the same urban spaces and have structural similarity. For integrating these two networks, urban design instruments are beneficial, which has been absent from prior efforts to integrate GI and compact city planning. Some important findings that emerged from this dissertation include identifying UPOSs as the shared space of GI and pedestrian connectivity, creating tabular urban design tools for blending GI and pedestrian connectivity, and developing design proposals for the demonstration of this integration.

5.1 Summary

This research was conducted in the Greater Toronto Area (GTA), located in Southern Ontario, where 25 UGCs across the region are currently undergoing intensification through the Growth Plan. This research context allowed a comparative case study approach to be utilized in examining the two selected UGCs of Downtown Mississauga and Markham Centre. The findings stemming from this comparison can be applied to other UGCs in Southern Ontario. The findings and contributions of this dissertation will be elaborated upon in the remainder of this paper.

The literature review provided a chronological overview of intensification planning and GI planning, which showed that despite their different policies and strategies, intensification and GI are intended to achieve a similar set of sustainability goals to combat urban sprawl. Therefore, it was demonstrated that GI could enhance intensification goals in various aspects of urban life, urban efficiency, and urban environment. Subsequently, existing research revealed that the implementation of GI and intensification strategies promote the same sustainability characteristics (e.g., connectivity and multifunctionality) for the built environment. A recent research trend suggests blending GI and compact city planning through the

co-development of their connectivity and multifunctionality characteristics. However, few design studies focus on the promotion of connectivity and multifunctionality in areas under intensification.

It was concluded from the literature review that in order to design built environments that are both compact and green, GI connectivity and pedestrian connectivity could be integrated. Pedestrian connectivity is the backbone of the process for transitioning away from car-oriented developments to transit-friendly and pedestrian-friendly environments in intensified urban areas. GI structural connectivity, on the other hand, is required for preserving, restoring, and developing natural and semi-natural features in urban areas. As GI connectivity and pedestrian connectivity have similar spatial characteristics and are developed in the same UPOSs, pedestrian networks can provide physical space for GI planning in areas under intensification, while GI can enhance pedestrian connectivity by creating a more pleasant environment for pedestrians. This highlights the significance of GI for promoting a means of active transportation as it provides multiple ecosystem services, including cultural ecosystem services (e.g., safety provision, and enhancing attractiveness). Hence, the focus of this dissertation was directed toward integrating GI and pedestrian connectivity in areas under intensification.

With regard to the methodology section of this dissertation, a case study and mixed method research approach were applied. The author's role as an observer and subject expert in architecture, urban design, and sustainability planning were disclosed. Regarding the case studies examined in this dissertation, by providing a brief background about the planning context in Southern Ontario, the reasons behind the selection of two UGCs in Southern Ontario were described. Both case studies have the same intensification targets and rapid/dynamic pace of development. However, there are planning differences due to a number of factors, such as the stage of development, environmental features and approach, and environmental issues.

For analyzing multiple data sources from case studies and addressing research questions, a mixed method research was designed. This method consumed extensive time and resources as it was designed to be implemented in three phases. The first phase included qualitative data collection and analyses using official plans, interviews, and site visits. The second phase performed meta-analyses from previous publications in order to generate two tabular urban design tools. The third phase described the development of urban design proposals created by the author of this dissertation in order to help fill the lack of design guidelines within the existing literature.

As this dissertation applied a case study comparative approach, similar built-environmental barriers for developing GI and pedestrian connectivity were found through the investigative research. Although both case studies identified plans for GI and pedestrian networks, these networks were fragmented by large-size urban blocks and car-oriented roads. Large-size urban blocks inhibited the penetration of ecosystem services from urban green spaces into intensified areas, which resulted in numerous environmental issues, including excessive generation of urban runoff. At the same time, despite the presence of numerous street frontages, pedestrian routes along large-size urban blocks were long and unattractive for pedestrians. Single-purpose roads were the major barriers impeding the movement of nutrients and species, leading to environmental issues, such as excessive road salt and creek erosion. Meanwhile, the speed and volume of car traffic created undesirable streets for pedestrians due to pollution, safety concerns, and long distances between the crosswalks.

Additionally, an overview of strategies for creating GI and pedestrian connectivity in both case studies was presented. For improving pedestrian connectivity, multifunctional streets and small/mix use blocks were suggested by applying various strategies to different UPOSs. The main strategies used were that of increasing street connectivity, improving pedestrian routes, and creating vibrant urban environments. In downtown Mississauga, the dense street grid was proposed to connect existing large parks and civic spaces in order to reduce large-size urban blocks, to smaller blocks with a 400m circumference. The proposed street grid was supplemented by parks, street trees, public plazas, and public art installations. However, for Markham Centre, increasing pedestrian connectivity was more challenging due to the protected Rouge Valley as well as the presence of development clusters by different developers. The city investigated limited strategies, such as adding street crossings to the Rouge Valley.

Both UGCs aimed to enhance street frontages for pedestrians. Downtown Mississauga mandated a five-minute walking distance from retail/residential frontages, while Markham Centre required a fifteen-minute walking distance. This was due to Markham Centre being a larger area than Downtown Mississauga. Both UGCs also considered surface parking areas as obstacles for pedestrian connectivity and tried to replace existing parking areas with small blocks of mixed-use developments. Both UGCs also tried to develop trail routes as a key strategy for improving pedestrian connectivity. Downtown Mississauga planned to create trails along its natural features, while Markham Centre proposed ten additional trail crossings and trails in buffer zones.

For GI connectivity, both UGCs planned to develop high-quality parks with selected plant species, intensive green spaces, and designed landscapes in multiple sizes. Downtown Mississauga planned a network of multi-size parks, including small property-size parks while Markham Centre expanded parks in the buffer zones of protected Rouge Valley. Both UGCs had GI restoration strategies, including daylighting the piped sections of the creeks in Downtown Mississauga and rehabilitating storm ponds in Markham Centre, with a focus on enhancing pedestrian accessibility for pedestrians and outdoor activities. Both UGCs also sought to transform surface parking areas with parks and equipping existing parking areas with LID features. Markham Centre also maintained a public interface between private and public green spaces to enhance GI connectivity. However, in both case studies, GI connectivity strategies along roads were limited to providing street trees.

The comparative case study results suggested that GI and pedestrian networks co-exist in UPOSs. Accordingly, supporting tools for the integration of GI and pedestrian networks were provided. This included identifying four categories of UPOSs, as the space for integrating GI and pedestrian connectivity. There were numerous UPOSs in the case studies, which could be used for promoting GI and pedestrian connectivity. From the comparison of case studies examined in this dissertation, examples of urban design interventions in UPOSs that support the notion of integrating GI and pedestrian networks, were found. This suggested that integrated GI and pedestrian networks in UPOSs provides considerable space for GI connectivity in intensified areas, while transforming the UPOSs into destinations for pedestrians.

Through the case study comparison process, it was subsequently determined that there were implementation gaps for developing an integrated network of GI and pedestrian routes. One of the findings from this research was that financial limitations often prevent the implementation of capital projects for GI and pedestrian networks. Another finding was that there was a lack of design guidelines for promoting GI and pedestrian connectivity. This resulted in the piecemeal and fragmented implementation of GI and pedestrian networks. There were three gaps identified for promoting GI connectivity. First, many case studies from all over the world present a diverse spectrum of nature-based solutions, however, only traditional green space development is advocated in the official plans of the two case studies examined in this research project. Second, it was determined that the capability of GI networks to produce ecosystem services has been overshadowed by the ability of GI to regulate

stormwater. Third, there are no universal design guidelines for promoting GI connectivity due to local environmental variables of GI elements.

In addition, there were three gaps found related to promoting pedestrian connectivity. First, case studies lacked interventions for increasing safety and promoting attractiveness. This discourages pedestrian activity. Second, there was a lack of human-scale development suitable for pedestrians due to the distance between pedestrian destinations and the large-size of buildings. Third, the existing interventions in pedestrian environments have been mostly focused on utilitarian pedestrians. Other purposes, such as recreational walking have been overshadowed.

For developing an integrated network of GI and pedestrian routes in intensified areas, two tabular design tools were presented. Table 4-2 presents a typology of GI elements, based on their structural properties, which can be developed in the identified UPOSs so that the GI elements that lack multifunctionality and pedestrian accessibility were excluded. Table 4-3 listed the interactions between GI elements and the built environment, which led to ecosystem services or disservices. It provides information about the physical conditions that lead to the creation or degradation of ecosystem services. This table prioritizes regulating services, and cultural services, that are necessary for the identified UPOSs, based on municipal issues and planning priorities.

Finally, a comprehensive design proposal was presented to show how the tools presented in section 4.8 could be used for urban design. This included all UPOSs, a variety of GI elements, and ecosystem services. A comprehensive study of the site, and its surrounding developments was performed using site visits, comprehensive plan reviews, and developer plan reviews. Accordingly, the need for ecosystem services and design strategies for the UPOSs were identified. The design proposal included interventions about urban structures, corridors, and delivering ecosystems while avoiding disservices. The integrated GI elements and pedestrian routes were presented in a blended manner with the surrounding neighborhood. Finally, the Google Earth measurements verified that the site is suitable for the proposed design. The proposed design served as a proof of concept for integrating GI and pedestrian networks. Since the designs were not limited by local environmental variables, they can be applied to any urban projects in the UGCs. As a result, this study's findings can help alleviate car-dependency and environmental issues associated with intensification practice in Southern Ontario.

5.2 Policy Recommendations

Based on the analysis in Chapter 4, several core principles emerge that should guide future policy development. These recommendations aim to address the challenges related to the limited available space for development, strategic integration, multifunctionality, connectivity, and cross-disciplinary collaboration to ensuring that GI implementation aligns with the intensification goals and sustainable urban development. Accordingly, the following four policy recommendations are identified:

1. Prioritizing the integration of GI and pedestrian connectivity

This Policy prioritizes the integration of GI and pedestrian networks in intensified areas to promote the multifunctionality of both GI and intensification through simultaneously enhancing walkability and ecosystem services provision. Accordingly, GI elements such as green corridors, bioswales, and street trees can be incorporated into urban pedestrian networks to create a connected environment, which is both green and pedestrian friendly. This policy is derived from the findings in Section 4.2.5, which demonstrate how combining GI and pedestrian networks can resolve space conflicts.

2. Developing and redeveloping UPOSs for both GI and pedestrian connectivity

This policy encourages developing and redeveloping pedestrian corridors and trails along roads, streets, and natural areas as well as repurposing underutilized lands such as brownfields, surface parking lots, and vacant spaces for GI implementation. These spaces offer opportunities for creating connected networks of GI that provide ecosystem services and mitigate environmental impacts of intensification, such as increased runoff volume and urban heat island effect. These areas, identified in Section 4.6.3, provide ideal opportunities for creating connected GI networks and offering necessary ecosystem services in intensified areas.

3. Mandating multifunctional design for limited UPOSs

This policy focuses on maximizing multifunctionality in design guidelines for intensified areas, where land scarcity is an issue. In intensification, design guidelines should serve multiple purposes, such as ecosystem services provision (e.g., stormwater management, air quality improvement, and biodiversity enhancement) while supporting human activities like recreation and active transportation. This

recommendation arises from the findings in Section 4.7, where the multifunctionality of GI is emphasized as a necessary approach in densely built environments.

4. Facilitating Cross-Disciplinary Collaboration in GI Planning

This policy promotes better coordination between urban planners, engineers, landscape architects, architects, and developers to ensure GI is integrated holistically within intensification projects. Collaborative governance structures enable shared goals of GI and intensification and streamline GI implementation by addressing implementation barriers, such as misaligned priorities and lack of communication between various sectors. This principal stems from the analysis in Section 4.7, which highlighted communication gaps as a major barrier to GI integration.

5. Promoting Collaborative Co-Design in GI Planning

This policy advocates for incorporating Indigenous perspectives through active collaboration with Indigenous knowledge keepers during the planning and design of UPOSs. Engaging these communities early in the design process ensures that culturally significant features and Traditional Ecological Knowledge (TEK) are integrated into urban landscapes of the intensified UGCs. This can include symbolic elements, such as Indigenous art or patterns, and functional contributions, like the use of native vegetation with ecological and cultural value. Collaborative co-design enriches the cultural relevance of GI projects while promoting sustainability and reconciliation goals (Hill, 2012; TRC, 2015).

5.3 Contribution

Due to rapid urbanization, it has become critical to understand how to deliver sustainable approaches through urban planning and development. Although the benefits of GI for sustainable development have been comprehensively acknowledged in research literature, their implementation has been incremental and challenging due to a lack of design standards. Developing design tools for integrating GI in intensification planning requires multidisciplinary research that can cover multiple fields, such as urban design and planning, transportation planning, and urban ecology. This dissertation, by examining multidisciplinary research, has identified relevant design tools for blending GI and intensification, that can not only address intensification issues, but also make GI mainstream in planning processes. These design tools have the capacity to assist a variety of design professionals and allied consultants, with integrating GI and intensification approaches. They also can provide an opportunity for urban planning

professionals to engage in a design dialogue with other disciplines such as landscape ecology and environmental science.

This dissertation answered a significant question of how to intensify urban areas while enhancing GI planning. The results demonstrate a design path toward sustainable development with step-by-step guidance. Although the path appears more challenging than the "business as usual" planning approaches that are typically used to implement GI and intensification, the results of this dissertation however offer a potentially feasible alternative for reconciling the design conflict between GI and intensification.

The findings of this dissertation highlight a number of planning and design gaps that impede the integration of GI and pedestrian connectivity in areas under intensification. To this end, the research findings also include several assessment tables and sample design guidelines/proposals for addressing the identified gaps. These tools can serve to encourage urban planners and designers to seek further solutions for reconciling GI with intensification and assist with identifying other implementation gaps in both GI and intensification planning.

Table 4-2 and Table 4-3 contribute to the knowledge base of urban planning, transportation planning, urban design, landscape architecture and architecture with regard to GI integration with intensification planning and opportunities for enhancing walkability. These two tables provide a list of GI elements that are suitable for specific UPOSs, such that based on available space in new development, infill, and retrofit projects, proper GI elements can be selected to maximize the benefits of GI for urban dwellers and especially pedestrians. Table 4-2 provides a comprehensive list of GI elements that can be implemented in four categories of UPOSs in areas under intensification. These two tables can help facilitate achieving GI multifunctionality in compact urban environments, while not only improving cultural ecosystem services, but also improving regulating ecosystem services in pedestrian realms, such as improving the air quality and reducing the noise pollution in the UPOSs.

As enhancing pedestrian connectivity is one of the major focuses of this dissertation, the findings can significantly assist transportation planners in reducing car dependency by developing UPOSs that are appealing for pedestrians. Applying the results from this work with a transportation planning lens can assist in maximizing cultural and regulating ecosystem services for pedestrians by arranging specific GI elements in favor of pedestrian connectivity.

Since the findings of this dissertation summarize scientific data from multiple disciplines, including, urban planning, urban design, urban ecology, and transportation planning it has created a collaborative realm for creating more sustainable urban environments. The design guidelines of this dissertation have not separated green and grey infrastructures as it offers the integration of GI and pedestrian networks, where humans, nature and the built environment can interact in harmony.

Accordingly, the following takeaways can be used to present this thesis as a series of journal articles:

1. GI and intensification: common grounds, conflicts, and potentials for integration

A comprehensive literature review discusses that whether GI and intensification strategies are similar, opposed, or complementary to identify the conflicts and opportunities of implementing them together. The findings suggest that the similar sustainability attributes of GI and intensification, including connectivity and multifunctionality are the common ground between these two, which can address their competition over space.

2. The built-environment barriers and implementation gaps of co-developing GI and pedestrian connectivity

The case-study research of this dissertation examines the current state of GI and intensification in areas under intensification to understand the real-world implications and barriers of integrating GI and intensification. The built-environment barriers of developing GI and pedestrian connectivity is recognized as well as a set of implementation gaps for integrating GI and intensification strategies in areas under intensification. The findings suggest that there is a lack of design guidelines and space provision to deal with these barriers and address the implementation gaps.

3. Blending GI and intensification through designing an integrated network of GI and pedestrians.

The key to address the space conflict between GI and intensification is promoting connectivity in shared UPOSs for both GI and pedestrian environments. This provides ecosystem services and promote walkability at the same time. The findings include one table of available UPOSs for

promoting both GI and pedestrian interventions as well as two tables of GI typology and GI ecosystem services and disservices. These tabular tools are based on the structural properties of GI elements and available UPOSs for implementing them. Accordingly, they can be used to design connected GI and Pedestrian networks in other similar UGCs. Finally, a design proposal is developed as a proof of concept.

5.4 Future Research

This dissertation contributed to the development of urban design tools for including GI in areas under intensification through integrating GI networks and pedestrian networks. It contributed to creating a comprehensive understanding of multidisciplinary interactions in UGCs. While the author of this dissertation tried to minimize the impact of subjective assumptions and limitations, it is important to be mindful of the following study limitations:

1. The author has a background in urban planning, urban design, architecture, and sustainable design. This may have unintentionally introduced bias to various aspects of the research process. Hence, this study may have limitations due to the incomplete knowledge of the author in additional relevant fields, such as environmental science, transportation planning, landscape design, and biology. This may have affected the overall comprehensiveness of the findings. In the future, further research may be beneficial in which researchers from other disciplines attempt to identify and bridge potential information gaps.
2. This dissertation focused on medium-size UGCs (i.e. with an intensification target of 200 residents/jobs per hectare) in the GTA. Although half of Southern Ontario UGCs are medium size, there are large UGCs with higher intensification targets, such as for the City of Toronto, where the planning context significantly differs from the medium-size UGCs. These larger UGCs require a higher demand for ecosystem services, a higher use of active transportation, smaller opportunities for development, and a lower availability of UPOSs. In addition, there are small-size UGCs outside the GTA ring, which are less populated and have more opportunities for new development projects. Conducting similar research for these categories of UGCs would likely provide a better understanding of both the barriers and opportunities for integrating GI in intensification.

3. This dissertation did not examine the institutional barriers for integrating GI and pedestrian networks. Future research may shed light on many of these, including: the compatibility of by-laws (regulatory barriers), lack of funding, siloed decision-making, public perceptions, and potential legal complexities.
4. This dissertation was focused on the design aspects of integrating GI and intensification. Further research that is more attentive to social variables about the integrated GI and pedestrian network (e.g., people's behavior, public preferences, and public perceptions), could potentially augment this work.
5. Further research is needed regarding provisioning and supporting ecosystem services in compact urban environments, as these ecosystem services are understudied in intensified areas. Subsequent research is needed to study the interactions between intensified urban development and GI elements to enhance provisioning and supporting ecosystem services.
6. This research focused on intensification and GI planning within the southern Ontario context as well as drawing upon studies from the broader Western context (primarily Europe, Canada, and the United States). Further research in other planning and environmental case studies is needed beyond this limited Western context. It is possible that different factors (e.g., climactic differences, sociopolitical variables, urban regulatory policies, environmental challenges) may influence the integration of GI and intensification differently in various regions of the world.
7. Subsequent research may benefit from utilizing a "research through design" approach to apply the design tools from this dissertation as a means of inquiry and experimentation. The follow up research could include design charrettes, prototyping, participatory design, and design feedback loops and workshops. This type of research could result in pragmatic improvements for reaching out to a wider audience and paving the way for mainstream implementation of the integrating GI and intensification.

References

Abhijith, K. V, Kumar, P., Gallagher, J., Mcnabola, A., Baldauf, R., Pilla, F., Broderick, B., Di, S., & Pulvirenti, B. (2017). Air pollution abatement performances of green infrastructure in open road and built-up street canyon environments e A review. *Atmospheric Environment*, *162*, 71–86. https://doi.org/10.1016/j.atmosenv.2017.05.014

Adkins, A., Dill, J., Luhr, G., & Neal, M. (2012). Unpacking Walkability: Testing the Influence of Urban Design Features on Perceptions of Walking Environment Attractiveness. *Journal of Urban Design*, *17*(4), 499–510. https://doi.org/10.1080/13574809.2012.706365

Ahern, J. (2016). Novel Urban Ecosystems: Concepts, Definitions and a Strategy to Support Urban Sustainability and Resilience. *Landscape Architecture Frontiers*, *4*(1), 10–21.

Ahern, Jack, Cilliers, S., & Niemelä, J. (2014). The concept of ecosystem services in adaptive urban planning and design: A framework for supporting innovation. *Landscape and Urban Planning*, *125*, 254–259. https://doi.org/10.1016/j.landurbplan.2014.01.020

Alizadehtazi, B., Gurian, P. L., & Montalto, F. A. (2020). Observed variability in soil moisture in engineered urban green infrastructure systems and linkages to ecosystem services. *Journal of Hydrology*, *590*(June), 125381. https://doi.org/10.1016/j.jhydrol.2020.125381

Allan, R., & Campsie, P. (2013). *Implementing the Growth Plan for the Greater Golden Horseshoe* (Issue October). http://www.neptis.org/publications/implementing-growth-plan-greater-golden-horseshoe

Allen, N., Haarhoff, E., & Beattie, L. (2018). Enhancing liveability through urban intensification: The idea and role of neighbourhood. *Cogent Social Sciences*, *4*(1). https://doi.org/10.1080/23311886.2018.1442117

Andersson, E., Barthel, S., Borgström, S., Colding, J., Elmqvist, T., Folke, C., & Gren, Å. (2014). Reconnecting cities to the biosphere: Stewardship of green infrastructure and urban ecosystem services. *Ambio*, *43*(4), 445–453. https://doi.org/10.1007/s13280-014-0506-y

Arnberger, A., & Eder, R. (2012). The influence of green space on community attachment of urban and suburban residents. *Urban Forestry and Urban Greening*, *11*(1), 41–49. https://doi.org/10.1016/j.ufug.2011.11.003

Artmann, M. (2016). Urban gray vs. urban green vs. soil protection — Development of a systemic solution to soil sealing management on the example of Germany. *Environmental Impact Assessment Review*, *59*, 27–42. https://doi.org/10.1016/j.eiar.2016.03.004

Artmann, M., Bastian, O., & Grunewald, K. (2017). Using the Concepts of Green Infrastructure and Ecosystem Services to Specify Leitbilder for Compact and Green Cities—The Example of the Landscape Plan of Dresden (Germany. *Sustainability*, *9*(2), 198. https://doi.org/10.3390/su9020198

Artmann, M., Kohler, M., Meinel, G., Gan, J., & Ioja, I. C. (2019). How smart growth and green infrastructure can mutually support each other — A conceptual framework for compact and green cities. *Ecological Indicators*, *96*(June 2017), 10–22. https://doi.org/10.1016/j.ecolind.2017.07.001

Barresi, A. (2018). Urban densification and energy efficiency in Smart cities-the VerGe project

(Switzerland). *Techne*, *SpecialSer*(01), 28–32. https://doi.org/10.13128/Techne-22713

Bartesaghi-Koc, C., Osmond, P., & Peters, A. (2019). Mapping and classifying green infrastructure typologies for climate-related studies based on remote sensing data. *Urban Forestry and Urban Greening*, *37*, 154–167. https://doi.org/10.1016/j.ufug.2018.11.008

Batchelor, J. P., Biancavilla, D., Hegemann, I., & Woodbury, C. D. (2016). Green infrastructure and transit-oriented mixed use development: The Alewife area of Cambridge, Massachusetts. *Journal of Green Building*, *11*(1), 1–22. https://doi.org/10.3992/jgb.11.1.1.1

Bednar, D., & Henstra, D. (2018). Applying a Typology of Governance Modes to Climate Change Adaptation. *Politics and Governance*, *6*(3), 147. https://doi.org/10.17645/pag.v6i3.1432

Beery, T. H., Raymond, C. M., Kyttä, M., Olafsson, A. S., Plieninger, T., Sandberg, M., Stenseke, M., Tengö, M., & Jönsson, K. I. (2017). Fostering incidental experiences of nature through green infrastructure planning. *Ambio*, *46*(7), 717–730. https://doi.org/10.1007/s13280-017-0920-z

Belaire, J. A., Westphal, L. M., Whelan, C. J., & Minor, E. S. (2015). Urban residents' perceptions of birds in the neighborhood: Biodiversity, cultural ecosystem services, and disservices. *Condor*, *117*(2), 192–202. https://doi.org/10.1650/CONDOR-14-128.1

Benedict, M. A., McMahon, E. T., Around, L., & European-Commission, E. (2006). Green Infrastructure. In *Island Press: Vol. May* (Issue 37). http://ec.europa.eu/environment/nature/info/pubs/docs/greeninfrastructure.pdf

Berardi, U., GhaffarianHoseini, A. A. H., & GhaffarianHoseini, A. A. H. (2014). State-of-the-art analysis of the environmental benefits of green roofs. *Applied Energy*, *115*, 411–428. https://doi.org/10.1016/j.apenergy.2013.10.047

Berkes, F. (2012). Sacred Ecology, Routledge. *New York & London*.

Berrigan, D., Pickle, L. W., & Dill, J. (2010). Associations between street connectivity and active transportation. *International Journal of Health Geographics*, *9*, 1–18. https://doi.org/10.1186/1476-072X-9-20

Bichajło, L., & Kołodziej, K. (2018). Porous asphalt pavement for traffic noise reduction and pavement dewatering-the pollution problem. *E3S Web of Conferences*, *45*, 0–5. https://doi.org/10.1051/e3sconf/20184500114

Black, J., Tara, K., & Pakzad, P. (2016). Mainstreaming green infrastructure elements into the design of public road reserves: Challenges for road authorities. *International Journal of Environmental Protection*, *6*(1), 1–15. https://doi.org/10.5963/IJEP0601001

Blair, R. B. (2001). Birds and Butterflies Along Urban Gradients in Two Ecoregions of the United States: Is Urbanization Creating a Homogeneous Fauna? In *Biotic Homogenization* (pp. 33–56). https://doi.org/10.1007/978-1-4615-1261-5_3

Blečić, I., Canu, D., Cecchini, A., Congiu, T., & Fancello, G. (2016). Factors of Perceived Walkability: A Pilot Empirical Study. In O. Gervasi, B. Murgante, S. Misra, A. M. A. C. Rocha, C. M. Torre, D. Taniar, B. O. Apduhan, E. Stankova, & S. Wang (Eds.), *Computational Science and Its Applications -- ICCSA 2016* (pp. 125–137). Springer International Publishing.

Bolliger, J., & Silbernagel, J. (2020). Contribution of connectivity assessments to green infrastructure (GI). *ISPRS International Journal of Geo-Information*, *9*(4). https://doi.org/10.3390/ijgi9040212

Boo, Y., & Kwon, Y. S. (2018). A Case Study on Sustainable Reuse of Abandoned Infrastructure at Seoul Station Overpass as Urban Park for the Design Strategies in Korea. *IOP Conference Series: Earth and Environmental Science*, *143*(1). https://doi.org/10.1088/1755-1315/143/1/012061

Brand, R., & Karvonen, A. (2007). The ecosystem of expertise: complementary knowledges for sustainable development. *Sustainability: Science, Practice, & Policy*, *3*(1), 21–31.

Breuste, J., & Artmann, M. (2020). Multi-functional Urban Green Spaces. In J. Breuste, M. Artmann, C. Ioja, & S. Qureshi (Eds.), *Making Green Cities: Concepts, Challenges and Practice* (pp. 399–526). Springer International Publishing. https://doi.org/10.1007/978-3-030-37716-8_7

Brown, B. B., Werner, C. M., Amburgey, J. W., & Szalay, C. (2007). Walkable route perceptions and physical features: Converging evidence for en route walking experiences. *Environment and Behavior*, *39*(1), 34–61. https://doi.org/10.1177/0013916506295569

Brunner, J., & Cozens, P. (2013). "Where Have All the Trees Gone?" Urban Consolidation and the Demise of Urban Vegetation: A Case Study from Western Australia. *Planning Practice and Research*, *28*(2), 231–255. https://doi.org/10.1080/02697459.2012.733525

Burgess, S. (2013). *12 Multifunctional green infrastructure : a typology* (pp. 227–241).

Byrne, J. A., Lo, A. Y., & Jianjun, Y. (2015). Residents' understanding of the role of green infrastructure for climate change adaptation in Hangzhou, China. *Landscape and Urban Planning*, *138*, 132–143. https://doi.org/10.1016/j.landurbplan.2015.02.013

Byrne, M. (2008). Greening RUnoff; THe Unsolved Nonpoint SOurce Pollution Problem, and Green Buildings Solution. *New York University Journal of Legislation and Public Policy*, *145*(c), 1–43. http://heinonline.org/HOL/License

Cadieux, K. V., Taylor, L. E., & Bunce, M. F. (2013). Landscape ideology in the Greater Golden Horseshoe Greenbelt Plan: Negotiating material landscapes and abstract ideals in the city's countryside. *Journal of Rural Studies*, *32*, 307–319. https://doi.org/10.1016/j.jrurstud.2013.07.005

Cain, K. L., Millstein, R. A., Sallis, J. F., Conway, T. L., Gavand, K. A., Frank, L. D., Saelens, B. E., Geremia, C. M., Chapman, J., Adams, M. A., Glanz, K., & King, A. C. (2014). Contribution of streetscape audits to explanation of physical activity in four age groups based on the Microscale Audit of Pedestrian Streetscapes (MAPS). *Social Science and Medicine*, *116*, 82–92. https://doi.org/10.1016/j.socscimed.2014.06.042

Caird, S. P., & Hallett, S. H. (2019). Towards evaluation design for smart city development. *Journal of Urban Design*, *24*(2), 188–209. https://doi.org/10.1080/13574809.2018.1469402

Calderón-Contreras, R., & Quiroz-Rosas, L. E. (2017). Analysing scale, quality and diversity of green infrastructure and the provision of Urban Ecosystem Services: A case from Mexico City. *Ecosystem Services*, *23*, 127–137. https://doi.org/10.1016/j.ecoser.2016.12.004

Caldwell, W., Epp, S., Wan, X., Singer, R., Drake, E., & Sousa, E. C. (2022). Farmland Preservation and Urban Expansion: Case Study of Southern Ontario, Canada. *Frontiers in Sustainable Food Systems*, *6*(February), 1–17. https://doi.org/10.3389/fsufs.2022.777816

Cameron, R. W. F. F., Blanuša, T., Taylor, J. E., Salisbury, A., Halstead, A. J., Henricot, B., & Thompson, K. (2012). The domestic garden - Its contribution to urban green infrastructure. *Urban Forestry and Urban Greening*, *11*(2), 129–137. https://doi.org/10.1016/j.ufug.2012.01.002

Canada, P. H. A. of. (2014). *Mobilizing Knowledge in Active Transportation*. https://www.canada.ca/content/dam/phac-aspc/migration/phac-aspc/hp-ps/hl-mvs/pa-ap/assets/pdfs/mkat-eng.pdf

Cao, Y., & Natuhara, Y. (2020). Effect of urbanization on vegetation in riparian area: Plant communities in artificial and semi-natural habitats. *Sustainability (Switzerland)*, *12*(1). https://doi.org/10.3390/su12010204

Casalegno, S., Anderson, K., Cox, D. T. C., Hancock, S., & Gaston, K. J. (2017). Ecological connectivity in the three-dimensional urban green volume using waveform airborne lidar. *Scientific Reports*, *7*(April), 1–8. https://doi.org/10.1038/srep45571

Cash, C. (2016). Good governance and strong political will: Are they enough for transformation? *Land Use Policy*, *50*, 301–311. https://doi.org/10.1016/j.landusepol.2015.10.009

Chaudhary, S., McGregor, A., Houston, D., & Chettri, N. (2015). The evolution of ecosystem services: A time series and discourse-centered analysis. *Environmental Science and Policy*, *54*, 25–34. https://doi.org/10.1016/j.envsci.2015.04.025

Cheng, M.-S., Coffman, L. S., & Clar, M. L. (2001). Low-impact development hydrologic analysis. *Urban Drainage Modeling*, *July*, 659–681. https://doi.org/10.1061/40583(275)63

Christman, Z., Meenar, M., Mandarano, L., & Hearing, K. (2018). Prioritizing suitable locations for green stormwater infrastructure based on social factors in Philadelphia. *Land*, *7*(4), 1–17. https://doi.org/10.3390/land7040145

Cidlowski, L., McGlynn, M., Stack, R. C., & Wooden, D. (2015). *Green Area Ratio Guidebook* (Vol. 26, Issue 2). District Department of Environment. %0Dwww.ddoe.dc.gov/gar

Cirella, G. (2020). *Advances in 21st Century Human Settlements*. https://doi.org/https://doi.org/10.1007/978-981-15-3049-4

City of Markham. (2020). *Markham Centre Secondary Plan Update*. *October*. https://pub-markham.escribemeetings.com/filestream.ashx?DocumentId=37505

City of Markham. (2021). *Markham Centre Secondary Plan Update*. https://pub-markham.escribemeetings.com/filestream.ashx?DocumentId=37505

City of Markham. (2022a). *Map of Vacant Lands*. https://maps.markham.ca/html5viewer/index.html?viewer=vacantland

City of Markham. (2022b). *Markham Centre Secondary Plan Update - Development Concept Report* (Issue July). www.yourvoicemarkham.ca/YourMarkhamCentre

City of Mississauga. (2010). *Downtown21 Master Plan* (Issue April). http://www6.mississauga.ca/onlinemaps/planbldg/images/DT21/Downtown21_FINAL_2010-04-08_web.pdf

City of Mississauga. (2013). *Downtown Core Built Form Standards*.

City of Mississauga. (2019). *Mississauga Stormwater 2019–2022 Business Plan& 2019 Budget*.

City of Mississauga. (2022). *2020 Vacant Lands Map of Mississauga*. https://mississauga.maps.arcgis.com/apps/opsdashboard/index.html#/c8f4b0810bf7409597fed76fdf71daf7

Connop, S., Vandergert, P., Eisenberg, B., Collier, M. J., Nash, C., Clough, J., & Newport, D. (2016). Renaturing cities using a regionally-focused biodiversity-led multifunctional benefits approach to urban green infrastructure. *Environmental Science and Policy*, *62*, 99–111. https://doi.org/10.1016/j.envsci.2016.01.013

Conticelli, E., Proli, S., & Tondelli, S. (2017). Integrating energy efficiency and urban densification policies: Two Italian case studies. *Energy and Buildings*, *155*, 308–323. https://doi.org/10.1016/j.enbuild.2017.09.036

Cornelissen, J. A. T. (1986). Dutch tourism; a big industry in a small country. *Tourism Management*, *7*(4), 294–297. https://doi.org/10.1016/0261-5177(86)90040-3

Cortesão, J., Lenzholzer, S., Klok, L., Jacobs, C., & Kluck, J. (2020). Generating applicable urban design knowledge. *Journal of Urban Design*, *25*(3), 293–307. https://doi.org/10.1080/13574809.2019.1650638

Cortesão, J., Lenzholzer, S., Mülder, J., Klok, L., Jacobs, C., & Kluck, J. (2020). Visual guidelines for climate-responsive urban design. *Sustainable Cities and Society*, *60*(April), 102245. https://doi.org/10.1016/j.scs.2020.102245

Costa, P., & Lopes, R. (2015). Urban Design, Public Space and the Dynamics of Creative Milieux: A Photographic Approach to Bairro Alto (Lisbon), Gràcia (Barcelona) and Vila Madalena (São Paulo). *Journal of Urban Design*, *20*(1), 28–51. https://doi.org/10.1080/13574809.2014.991382

Coutts, C., Wenger, R., & Duncan, M. (2019). Exploratory Analysis of Revealed Pedestrian Paths as Cues for Designing Pedestrian Infrastructure. *Journal of Urban Planning and Development*, *145*(4). https://doi.org/10.1061/(ASCE)UP.1943-5444.0000539

Cox, D. T. C., Hudson, H. L., Plummer, K. E., Siriwardena, G. M., Anderson, K., Hancock, S., Devine-Wright, P., & Gaston, K. J. (2018). Covariation in urban birds providing cultural services or disservices and people. *Journal of Applied Ecology*, *55*(5), 2308–2319. https://doi.org/10.1111/1365-2664.13146

Cui, J., & Nelson, J. D. (2019). Underground transport: An overview. *Tunnelling and Underground Space Technology*, *87*(February), 122–126. https://doi.org/10.1016/j.tust.2019.01.003

Dal Ferro, N., De Mattia, C., Gandini, M. A., Maucieri, C., Stevanato, P., Squartini, A., & Borin, M. (2021). Green walls to treat kitchen greywater in urban areas: Performance from a pilot-scale experiment. *Science of the Total Environment*, *757*, 144189. https://doi.org/10.1016/j.scitotenv.2020.144189

Dardir, M., & Berardi, U. (2021). Development of microclimate modeling for enhancing neighborhood thermal performance through urban greenery cover. *Energy and Buildings*, *252*, 111428. https://doi.org/10.1016/J.ENBUILD.2021.111428

Davies, C., Hansen, R., Rall, E., Pauleit, S., Lafortezza, R., De Bellis, Y., Santos, A., & Tosics, I. (2015).

Green Infrastructure Planning and Implementation. *March*, 134.

Davies, C., & Lafortezza, R. (2017). Urban green infrastructure in Europe: Is greenspace planning and policy compliant? *Land Use Policy*, *69*, 93–101. https://doi.org/10.1016/j.landusepol.2017.08.018

De Groot, R., Fisher, B., Christie, M., Aronson, J., Braat, L., Gowdy, J., Haines-Young, R., Maltby, E., Neuville, A., Polasky, S., Portela, R., Ring, I., Blignaut, J., Brondízio, E., Costanza, R., Jax, K., Kadekodi, G. K., May, P. H., Mc Neely, J. A., … Kadekodi, G. K. (2012). Integrating the ecological and economic dimensions in biodiversity and ecosystem service valuation. In *The Economics of Ecosystems and Biodiversity: Ecological and Economic Foundations* (Issue March, pp. 9–40). https://doi.org/10.4324/9781849775489

De Sousa, C. (2017). Trying to smart-in-up and cleanup our act by linking regional growth planning, brownfields remediation, and Urban infill in Southern Ontario cities. *Urban Planning*, *2*(3), 5–17. https://doi.org/10.17645/up.v2i3.1026

De Sousa, C. A., & Spiess, T. B. (2018). The management of brownfields in Ontario: A comprehensive review of remediation and reuse characteristics, trends, and outcomes, 2004–2015. *Environmental Practice*, *20*(1), 4–15. https://doi.org/10.1080/14660466.2018.1407615

De Sousa, C., & Ridsdale, D. R. (2021). An examination of municipal efforts to manage brownfields redevelopment in Ontario, Canada. *Canadian Journal of Urban Research*, *30*(1), 99–114.

Delso, J., Martín, B., Ortega, E., & Van De Weghe, N. (2019). Integrating pedestrian-habitat models and network kernel density estimations to measure street pedestrian suitability. *Sustainable Cities and Society*, *51*(July), 101736. https://doi.org/10.1016/j.scs.2019.101736

Di Giulio, M., Holderegger, R., & Tobias, S. (2009). Effects of habitat and landscape fragmentation on humans and biodiversity in densely populated landscapes. *Journal of Environmental Management*, *90*(10), 2959–2968. https://doi.org/10.1016/j.jenvman.2009.05.002

Dill, J. (2004). Measuring network connectivity for bicycling and walking. *83rd Annual Meeting of the Transportation …*, *1*, 20. http://reconnectingamerica.org/assets/Uploads/TRB2004-001550.pdf

Dobbs, C., Kendal, D., & Nitschke, C. R. (2014). Multiple ecosystem services and disservices of the urban forest establishing their connections with landscape structure and sociodemographics. *Ecological Indicators*, *43*, 44–55. https://doi.org/10.1016/j.ecolind.2014.02.007

Dorning, M. A., Koch, J., Shoemaker, D. A., & Meentemeyer, R. K. (2015). Simulating urbanization scenarios reveals tradeoffs between conservation planning strategies. *Landscape and Urban Planning*, *136*, 28–39. https://doi.org/10.1016/j.landurbplan.2014.11.011

Drillet, Z., Fung, T. K., Leong, R. A. T., Sachidhanandam, U., Edwards, P., & Richards, D. (2020). Urban vegetation types are not perceived equally in providing ecosystem services and disservices. *Sustainability (Switzerland)*, *12*(5). https://doi.org/10.3390/su12052076

Droste, N., D'Amato, D., & Goddard, J. J. (2018). Where communities intermingle, diversity grows – The evolution of topics in ecosystem service research. *PLoS ONE*, *13*(9), 7–8. https://doi.org/10.1371/journal.pone.0204749

Duffhues, J., & Bertolini, L. (2016). From integrated aims to fragmented outcomes: Urban intensification and transportation planning in the Netherlands. *Journal of Transport and Land Use*, *9*(3), 15–34.

https://doi.org/10.5198/jtlu.2016.571

Dumitru, A., Frantzeskaki, N., & Collier, M. (2020). Identifying principles for the design of robust impact evaluation frameworks for nature-based solutions in cities. *Environmental Science and Policy*, *112*(May), 107–116. https://doi.org/10.1016/j.envsci.2020.05.024

Dushkova, D., & Haase, D. (2020). Not simply green: Nature-based solutions as a concept and practical approach for sustainability studies and planning agendas in cities. *Land*, *9*(1). https://doi.org/10.3390/land9010019

Ellis, G., Hunter, R., Tully, M. A., Donnelly, M., Kelleher, L., & Kee, F. (2016). Connectivity and physical activity: using footpath networks to measure the walkability of built environments. *Environment and Planning B: Planning and Design*, *43*(1), 130–151. https://doi.org/10.1177/0265813515610672

Erker, T., & Townsend, P. A. (2019). Trees in cool climate cities may increase atmospheric carbon by altering building energy use. *Environmental Research Communications*, *1*(8). https://doi.org/10.1088/2515-7620/ab37fd

Escobedo, F. J., Giannico, V., Jim, C. Y., Sanesi, G., & Lafortezza, R. (2019). Urban forests, ecosystem services, green infrastructure and nature-based solutions: Nexus or evolving metaphors? *Urban Forestry and Urban Greening*, *37*(November 2017), 3–12. https://doi.org/10.1016/j.ufug.2018.02.011

Escobedo, F. J., Kroeger, T., & Wagner, J. E. (2011). Urban forests and pollution mitigation: Analyzing ecosystem services and disservices. *Environmental Pollution*, *159*(8–9), 2078–2087. https://doi.org/10.1016/j.envpol.2011.01.010

European Commission's Directorate-General Environment. (2012). *The Multifunctionality of Green Infrastructure The Multifunctionality of Green Infrastructure* (Issue March 2012).

Everett, G., Lamond, J. E., Morzillo, A. T., Matsler, A. M., & Chan, F. K. S. (2015). Delivering Green Streets: An exploration of changing perceptions and behaviours over time around bioswales in Portland, Oregon. *Journal of Flood Risk Management*, 1–13. https://doi.org/10.1111/jfr3.12225

Ewing, R., Hajrasouliha, A., Neckerman, K. M., Purciel-Hill, M., & Greene, W. (2016). Streetscape Features Related to Pedestrian Activity. *Journal of Planning Education and Research*, *36*(1), 5–15. https://doi.org/10.1177/0739456X15591585

Fabos, J. G. (1995). Introduction and overview: the greenway movement, uses and potentials of greenways. *Landsc Urban Plan*, *33*, 1–13.

Filion, P. (2003). Towards Smart Growth? the Difficult Implementation of Alternatives To Urban Dispersion. *Canadian Journal of Urban Research*, *12*(1), 48–70. http://search.proquest.com/docview/208716797?accountid=34489%0Ahttp://atoz.ebsco.com/titles.asp?lang=&lang.subject=&lang.menu=&KW=&sid=258657917&id=1811&SF=Titles&ST=Contains&cmdSearchSubmit=BuscarCanadian+Journal+of+Urban+Research/

Filion, P. (2007). *The urban growth centres strategy in the Greater Golden Horseshoe: lessons from downtowns, nodes, and corridors*. *May*, 1–164. http://www.neptis.org/sites/default/files/nodes_and_corridors/filion_electronic_report_20070528.pd

f

Filion, P., & McSpurren, K. (2007). Smart growth and development reality: The difficult co-ordination of land use and transport objectives. *Urban Studies*, *44*(3), 501–524. https://doi.org/10.1080/00420980601176055

Filion, P., & Saboonian, S. (2019). Large multifunctional suburban centres and the transformation of the suburban realm. *Journal of Urbanism*, *12*(3), 296–319. https://doi.org/10.1080/17549175.2019.1576759

Firehock, K., & Walker, R. A. (2015). Strategic Green Infrastructure Planning : A Multi-scale Approach. In *Island Press*. http://search.ebscohost.com/login.aspx?direct=true&db=nlebk&AN=1067716&lang=fr&site=ehost-live%5Cnhttp://content.ebscohost.com/ContentServer.asp?T=P&P=AN&K=1067716&S=R&D=nlebk&EbscoContent=dGJyMNLe80SeqLY4yNfsOLCmr06eprZSsKu4TK6WxWXS&ContentCustomer=dGJyM

Food and Agricultural Organization of the United Nations. (2022). *Ecosystem Services & Biodiversity (ESB)*. typology of The Economics of Ecosystems and Biodiversity (TEEB)

Forsyth, A. (2015). What is a walkable place? The walkability debate in urban design. *Urban Design International*, *20*(4), 274–292. https://doi.org/10.1057/udi.2015.22

Forsyth, A., Oakes, J. M., Schmitz, K. H., & Hearst, M. (2007). Does residential density increase walking and other physical activity? *Urban Studies*, *44*(4), 679–697. https://doi.org/10.1080/00420980601184729

Foster, J., Lowe, A., & Winkelman, S. (2011). The Value of Green Infrastructure for Urban Climate Adaptation. In *The Center for Clean Air Policy* (Issue February).

Francis, J., Giles-Corti, B., Wood, L., & Knuiman, M. (2012). Creating sense of community: The role of public space. *Journal of Environmental Psychology*, *32*(4), 401–409. https://doi.org/10.1016/j.jenvp.2012.07.002

Galster, G., Hanson, R., Ratcliffe, M. R., Wolman, H., Coleman, S., & Freihage, J. (2001). Wrestling sprawl to the ground: Defining and measuring an elusive concept. *Housing Policy Debate*, *12*(4), 681–717. https://doi.org/10.1080/10511482.2001.9521426

Gardiner, M. M., Burkman, C. E., & Prajzner, S. P. (2013). The value of urban vacant land to support arthropod biodiversity and ecosystem services. *Environmental Entomology*, *42*(6), 1123–1136. https://doi.org/10.1603/EN12275

Gavrilidis, A. A., Niţă, M. R., Onose, D. A., Badiu, D. L., Năstase, I. I., Niță, M. R., Onose, D. A., Badiu, D. L., & Năstase, I. I. (2017). Methodological framework for urban sprawl control through sustainable planning of urban green infrastructure. *Ecological Indicators*, *96*(October 2016), 67–78. https://doi.org/10.1016/j.ecolind.2017.10.054

Gehl, J. (2013). *Cities for people*. Island press.

Gidlow, C., Cochrane, T., Davey, R. C., Smith, G., & Fairburn, J. (2010). Relative importance of physical and social aspects of perceived neighbourhood environment for self-reported health. *Preventive Medicine*, *51*(2), 157–163. https://doi.org/10.1016/j.ypmed.2010.05.006

Giles-Corti, B., Wood, G., Pikora, T., Learnihan, V., Bulsara, M., Van Niel, K., Timperio, A., McCormack, G., & Villanueva, K. (2011). School site and the potential to walk to school: The impact of street connectivity and traffic exposure in school neighborhoods. *Health and Place*, *17*(2), 545–550. https://doi.org/10.1016/j.healthplace.2010.12.011

Gillies, C. S., & St. Clair, C. C. (2008). Riparian corridors enhance movement of a forest specialist bird in fragmented tropical forest. *Proceedings of the National Academy of Sciences of the United States of America*, *105*(50), 19774–19779. https://doi.org/10.1073/pnas.0803530105

Gkiatas, G., Kasapidis, I., Koutalakis, P., Iakovoglou, V., Savvopoulou, A., Germantzidis, I., & Zaimes, G. N. (2021). Enhancing urban and sub-urban riparian areas through ecosystem services and ecotourism activities. *Water Supply*, *21*(6), 2974–2988. https://doi.org/10.2166/ws.2021.114

Gómez-Baggethun, E., & Barton, D. N. (2013). Classifying and valuing ecosystem services for urban planning. *Ecological Economics*, *86*, 235–245. https://doi.org/10.1016/j.ecolecon.2012.08.019

Google. (2023). *Google Earth Pro*. https://www.earth.google.com

Grabow, M. L., Bernardinello, M., Bersch, A. J., Engelman, C. D., Martinez-Donate, A., Patz, J. A., Peppard, P. E., & Malecki, K. M. C. (2019). What moves us: Subjective and objective predictors of active transportation. *Journal of Transport and Health*, *15*(August), 100625. https://doi.org/10.1016/j.jth.2019.100625

Green Infrastructure Foundation. (2018). *Green Infrastructure in Mississauga, Richmond Hill, and Toronto*. https://greeninfrastructurefoundation.org/resources

Green Roofs for Healthy Cities. (2015). *GREEN INFRASTRUCTURE Making the Case for Green Infrastructure Investment in*. https://greeninfrastructurefoundation.org/resources

Griffith, J. C. (2010). Green Infrastructure: The Imperative of Open Space Preservation. *The Urban Lawyer*, *42/43*(4/1), 259–306. https://doi.org/http://dx.doi.org/10.1108/17506200710779521

Gunawardena, K. R., Wells, M. J., & Kershaw, T. (2017). Utilising green and bluespace to mitigate urban heat island intensity. *Science of the Total Environment*, *584–585*, 1040–1055. https://doi.org/10.1016/j.scitotenv.2017.01.158

Haaland, C., & van den Bosch, C. K. (2015). Challenges and strategies for urban green-space planning in cities undergoing densification: A review. *Urban Forestry and Urban Greening*, *14*(4), 760–771. https://doi.org/10.1016/j.ufug.2015.07.009

Haase, D., Kabisch, S., Haase, A., Andersson, E., Banzhaf, E., Baró, F., Brenck, M., Fischer, L. K., Frantzeskaki, N., Kabisch, N., Krellenberg, K., Kremer, P., Kronenberg, J., Larondelle, N., Mathey, J., Pauleit, S., Ring, I., Rink, D., Schwarz, N., & Wolff, M. (2017). Greening cities – To be socially inclusive? About the alleged paradox of society and ecology in cities. *Habitat International*, *64*, 41–48. https://doi.org/10.1016/j.habitatint.2017.04.005

Han, A. T., Graham, R., & Tsenkova, S. (2020). The Inside and Outside Game of Growth Management: Tracking Sprawl of Canada's Largest Metropolitan Areas. *Journal of Planning Education and Research*. https://doi.org/10.1177/0739456X20937335

Hanchard, Q. (2021). *Unionville Subcommittee Meeting Markham Centre Secondary Plan Update Markham Centre Context*.

Handy, S. L., Butler, K. S., & Paterson, R. G. (2003). *PAS Report 515 Planning for Street Connectivity—Getting from here to there*. *515*.

Hansen, R., Olafsson, A. S., van der Jagt, A. P. N., Rall, E., Pauleit, S., Stahl, A., Jagt, A. P. N. Van Der, Rall, E., & Pauleit, S. (2019). Planning multifunctional green infrastructure for compact cities: What is the state of practice? *Ecological Indicators*, *96*(November 2017), 99–110. https://doi.org/10.1016/j.ecolind.2017.09.042

Hansen, R., & Pauleit, S. (2014). From multifunctionality to multiple ecosystem services? A conceptual framework for multifunctionality in green infrastructure planning for Urban Areas. *Ambio*, *43*(4), 516–529. https://doi.org/10.1007/s13280-014-0510-2

Hashad, K., Yang, B., Baldauf, R. W., Deshmukh, P., Isakov, V., & Zhang, K. M. (2020). Enhancing the local air quality benefits of roadside green infrastructure using low-cost, impermeable, solid structures (LISS). *Science of the Total Environment*, *717*, 137136. https://doi.org/10.1016/j.scitotenv.2020.137136

Heins, M. (2015). Finding Common Ground Between New Urbanism and Landscape Urbanism. *Journal of Urban Design*, *20*(3), 293–302. https://doi.org/10.1080/13574809.2015.1031002

Hennig, E. I., Schwick, C., Soukup, T., Orlitová, E., Kienast, F., & Jaeger, J. A. G. (2015). Multi-scale analysis of urban sprawl in Europe: Towards a European de-sprawling strategy. *Land Use Policy*, *49*, 483–498. https://doi.org/10.1016/j.landusepol.2015.08.001

Hill, S. M. (2017). *The clay we are made of: Haudenosaunee land tenure on the Grand River* (Vol. 20). Univ. of Manitoba Press.

Hislop, M., Scott, A. J., & Corbett, A. (2019). What Does Good Green Infrastructure Planning Policy Look Like? Developing and Testing a Policy Assessment Tool Within Central Scotland UK. *Planning Theory and Practice*, *20*(5), 633–655. https://doi.org/10.1080/14649357.2019.1678667

Hoctor, T., Allen, W., Carr, M., Zwick, P., Huntley, E., Smith, D., & Maehr, D. (2008). Land corridors in the southeast: connectivity to protect biodiversity and ecosystem services. *Journal of Conservation Planning*, *4*, 90–122. http://fwcg.myfwc.com/docs/Wildlife_Corridors_Hoctor_2007.pdf

Höglund, P. G. (2004). Parking, energy consumption and air pollution. *Science of the Total Environment*, *334–335*, 39–45. https://doi.org/10.1016/j.scitotenv.2004.04.028

Honey-Rosés, J., Anguelovski, I., Bohigas, J., Chireh, V., Daher, C., Konijnendijk, C., Litt, J., Mawani, V., McCall, M., Orellana, A., Oscilowicz, E., Sánchez, U., Senbel, M., Tan, X., Villagomez, E., Zapata, O., & Nieuwenhuijsen, M. (2020). The Impact of COVID-19 on Public Space : A Review of the Emerging Questions. *Preprint*, *April*, 1–20. https://doi.org/10.31219/osf.io/rf7xa

Hong, J. Y., & Jeon, J. Y. (2013). Designing sound and visual components for enhancement of urban soundscapes. *The Journal of the Acoustical Society of America*, *134*(3), 2026–2036. https://doi.org/10.1121/1.4817924

Hughey, S. M., Walsemann, K. M., Child, S., Powers, A., Reed, J. A., & Kaczynski, A. T. (2016). Landscape and Urban Planning Using an environmental justice approach to examine the relationships between park availability and quality indicators , neighborhood disadvantage , and racial / ethnic composition. *Landscape and Urban Planning*, *148*, 159–169.

https://doi.org/10.1016/j.landurbplan.2015.12.016

Hui, L. C., & Jim, C. Y. (2022). Land Use Policy Urban-greenery demands are affected by perceptions of ecosystem services and disservices , and socio-demographic and environmental-cultural factors. *Land Use Policy*, *120*(June), 106254. https://doi.org/10.1016/j.landusepol.2022.106254

Hunter, M. C. R., & Brown, D. G. (2012). Spatial contagion: Gardening along the street in residential neighborhoods. *Landscape and Urban Planning*, *105*(4), 407–416. https://doi.org/10.1016/j.landurbplan.2012.01.013

Ignatieva, M., Stewart, G. H., & Meurk, C. (2011). Planning and design of ecological networks in urban areas. *Landscape and Ecological Engineering*, *7*(1), 17–25. https://doi.org/10.1007/s11355-010-0143-y

Indigenous and Northern Affairs Canada (2013). "Treaties and Agreements."

Institute of Medicine, & National Research Council. (2013). U. S. Health in International Perspecitive Shorter Lives, Poorer Health. Panel on Understanding Cross-National Health Differences among High-Income Countries. In *Govt Reports Announcements & Index (GRA&I), Issue 14*, *2013*.

Institute without Boundaries. (2012). *Creative Convergence Hubs Charrette*. https://institutewithoutboundaries.ca/?portfolio=creative-convergence-hubs-charrette

Iojă, C. I., Grădinaru, S. R., Onose, D. A., Vânău, G. O., & Tudor, A. C. (2014). The potential of school green areas to improve urban green connectivity and multifunctionality. *Urban Forestry and Urban Greening*, *13*(4), 704–713. https://doi.org/10.1016/j.ufug.2014.07.002

Iravani, H., & Rao, V. (2020). The effects of New Urbanism on public health. *Journal of Urban Design*, *25*(2), 218–235. https://doi.org/10.1080/13574809.2018.1554997

Jabareen, Y. R. (2006). Sustainable Urban Forms: Their Typologies, Models, and Concepts. *Journal of Planning Education and Research*, *26*(1), 38–52. https://doi.org/10.1177/0739456X05285119

Jabbari, M., Fonseca, F., Smith, G., Conticelli, E., Tondelli, S., Ribeiro, P., Ahmadi, Z., Papageorgiou, G., & Ramos, R. (2023). The Pedestrian Network Concept : A Systematic Literature Review. *Journal of Urban Mobility*, *3*(March), 100051. https://doi.org/10.1016/j.urbmob.2023.100051

Jerome, G. (2017). Defining community-scale green infrastructure. *Landscape Research*, *42*(2), 223–229. https://doi.org/10.1080/01426397.2016.1229463

Jerome, G., Mell, I., & Shaw, D. (2017). Re-defining the characteristics of environmental volunteering: Creating a typology of community-scale green infrastructure. *Environmental Research*, *158*(May), 399–408. https://doi.org/10.1016/j.envres.2017.05.037

Jia, Z., Tang, S., Luo, W., Li, S., & Zhou, M. (2016). Small scale green infrastructure design to meet different urban hydrological criteria. *Journal of Environmental Management*, *171*, 92–100. https://doi.org/10.1016/j.jenvman.2016.01.016

Jim, C. Y. (2004). Green-space preservation and allocation for sustainable greening of compact cities. *Cities*, *21*(4), 311–320. https://doi.org/10.1016/j.cities.2004.04.004

Jim, C. Y. (2012). Sustainable urban greening strategies for compact cities in developing and developed economies. *Urban Ecosystems 2012 16:4*, *16*(4), 741–761. https://doi.org/10.1007/S11252-012-

0268-X

Jim, C. Y. (2015). Greenwall classification and critical design-management assessments. *Ecological Engineering*, *77*, 348–362. https://doi.org/10.1016/j.ecoleng.2015.01.021

Joh, K., Chakrabarti, S., Boarnet, M. G., & Woo, A. (2015). The walking renaissance: A longitudinal analysis of walking travel in the Greater Los Angeles Area, USA. *Sustainability (Switzerland)*, *7*(7), 8985–9011. https://doi.org/10.3390/SU7078985

Kabisch, N. (2015). Ecosystem service implementation and governance challenges in urban green space planning-The case of Berlin, Germany. *Land Use Policy*, *42*, 557–567. https://doi.org/10.1016/j.landusepol.2014.09.005

Kambites, C., & Owen, S. (2006). Renewed prospects for green infrastructure planning in the UK 1. *Planning Practice and Research*, *21*(4), 483–496. https://doi.org/10.1080/02697450601173413

Kang, B., Moudon, A. V., Hurvitz, P. M., & Saelens, B. E. (2017). Differences in behavior, time, location, and built environment between objectively measured utilitarian and recreational walking. *Transportation Research Part D: Transport and Environment*, *57*(October), 185–194. https://doi.org/10.1016/j.trd.2017.09.026

Karvonen, A. (2011). Reasserting the Place of Nature in Seattle's Urban Creeks. In *Politics of urban runoff: nature, technology, and the sustainable city. MIT Press.*

Karvonen, Andrew, & Yocom, K. (2011). The civics of urban nature: Enacting hybrid landscapes. *Environment and Planning A*, *43*(6), 1305–1322. https://doi.org/10.1068/a43382

Kazemi, F., Beecham, S., & Gibbs, J. (2011). Streetscape biodiversity and the role of bioretention swales in an Australian urban environment. *Landscape and Urban Planning*, *101*(2), 139–148. https://doi.org/10.1016/j.landurbplan.2011.02.006

Keeley, M. (2011). The green area ratio: An urban site sustainability metric. *Journal of Environmental Planning and Management*, *54*(7), 937–958. https://doi.org/10.1080/09640568.2010.547681

Keeley, M., Koburger, A., Dolowitz, D. P., Medearis, D., Nickel, D., & Shuster, W. (2013). Perspectives on the use of green infrastructure for stormwater management in cleveland and milwaukee. *Environmental Management*, *51*(6), 1093–1108. https://doi.org/10.1007/s00267-013-0032-x

Keith, M., Birch, E., Buchoud, N. J. A., Cardama, M., Cobbett, W., Cohen, M., Elmqvist, T., Espey, J., Hajer, M., Hartmann, G., Matsumoto, T., Parnell, S., Revi, A., Roberts, D. C., Saiz, E., Schwanen, T., Seto, K. C., Tuts, R., & Van Der Pütten, M. (2023). *nature sustainability A new urban narrative for sustainable development*. *6*. https://doi.org/10.1038/s41893-022-00979-5

Kendall, R. (2013). *Markham Centre Mobility Hub Study*.

Kim, D., & Song, S. K. (2019). The multifunctional benefits of green infrastructure in community development: An analytical review based on 447 cases. *Sustainability (Switzerland)*, *11*(14), 1–17. https://doi.org/10.3390/su11143917

Kim, G., Miller, P. A., & Nowak, D. J. (2015). Assessing urban vacant land ecosystem services: Urban vacant land as green infrastructure in the City of Roanoke, Virginia. *Urban Forestry and Urban Greening*, *14*(3), 519–526. https://doi.org/10.1016/j.ufug.2015.05.003

Kim, G., Miller, P. A., & Nowak, D. J. (2018). Urban vacant land typology: A tool for managing urban vacant land. *Sustainable Cities and Society*, *36*(September 2016), 144–156. https://doi.org/10.1016/j.scs.2017.09.014

Kimmerer, R. (2013). *Braiding sweetgrass: Indigenous wisdom, scientific knowledge and the teachings of plants*. Milkweed editions.

King, G., Roland-Mieszkowski, M., Jason, T., & Rainham, D. G. (2012). Noise levels associated with urban land use. *Journal of Urban Health*, *89*(6), 1017–1030. https://doi.org/10.1007/s11524-012-9721-7

Kirnbauer, M., & Baetz, B. (2014). Prototype Decision-Support System for Designing and Costing Municipal Green Infrastructure. *Journal of Urban Planning and Development*, *140*(3), 04014004. https://doi.org/10.1061/(ASCE)UP.1943-5444.0000191

Kondolf, G. M., & Pinto, P. J. (2017). The social connectivity of urban rivers. *Geomorphology*, *277*, 182–196. https://doi.org/10.1016/j.geomorph.2016.09.028

Koohsari, M. J., Oka, K., Owen, N., & Sugiyama, T. (2019). Natural movement: A space syntax theory linking urban form and function with walking for transport. *Health and Place*, *58*(October 2018), 102072. https://doi.org/10.1016/j.healthplace.2019.01.002

Koschinsky, J., Talen, E., Alfonzo, M., & Lee, S. (2017). How walkable is Walker's paradise? *Environment and Planning B: Urban Analytics and City Science*, *44*(2), 343–363. https://doi.org/10.1177/0265813515625641

Kousky, C., Olmstead, S. M., Walls, M. a, & Macauley, M. (2013). *Strategically Placing Green Infrastructure : Cost-E ff ective Land Conservation in the Floodplain*. https://doi.org/10.1021/es303938c

Kowarik, I. (2018). Urban wilderness: Supply, demand, and access. *Urban Forestry and Urban Greening*, *29*(May 2017), 336–347. https://doi.org/10.1016/j.ufug.2017.05.017

KOWARIK, I. (2021). Working With Wilderness: A Promising Direction for Urban Green Spaces. *Landscape Architecture Frontiers*, *9*(1), 92. https://doi.org/10.15302/j-laf-1-030025

Kowarik, I., Straka, T. M., Lehmann, M., Studnitzky, R., & Fischer, L. K. (2021). Between approval and disapproval: Citizens' views on the invasive tree Ailanthus altissima and its management. *NeoBiota*, *65*, 1–30. https://doi.org/10.3897/NEOBIOTA.66.63460

Koyata, H., Iwachido, Y., Inagaki, K., Sato, Y., Tani, M., Ohno, K., Sadohara, S., & Sasaki, T. (2021). Factors determining on-site perception of ecosystem services and disservices from street trees in a densely urbanized area. *Urban Forestry and Urban Greening*, *58*(May 2020), 126898. https://doi.org/10.1016/j.ufug.2020.126898

Krauze, K., & Wagner, I. (2019). From classical water-ecosystem theories to nature-based solutions — Contextualizing nature-based solutions for sustainable city. *Science of the Total Environment*, *655*, 697–706. https://doi.org/10.1016/j.scitotenv.2018.11.187

Kubursi, A. (2012). The economic impact of remedial action plans: Case studies from Ontario. *Great Lakes: Lessons in Participatory Governance*, 132–164.

Kumar, P., Druckman, A., Gallagher, J., Gatersleben, B., Allison, S., Eisenman, T. S., Hoang, U., Hama, S., Tiwari, A., Sharma, A., Abhijith, K. V., Adlakha, D., McNabola, A., Astell-Burt, T., Feng, X., Skeldon, A. C., de Lusignan, S., & Morawska, L. (2019). The nexus between air pollution, green infrastructure and human health. *Environment International*, *133*(September), 105181. https://doi.org/10.1016/j.envint.2019.105181

Kuo, F. E., & Sullivan, W. C., Kuo, F. E., & Sullivan, W. C. (2001). Environment and crime in the inner city: Does vegetation reduce crime? *Environment and Behavior*, *33*(3), 343–367. https://doi.org/10.1177/0013916501333002

Lafortezza, R., & Sanesi, G. (2019). Nature-based solutions: Settling the issue of sustainable urbanization. *Environmental Research*, *172*, 394–398. https://doi.org/10.1016/j.envres.2018.12.063

Langemeyer, J., Wedgwood, D., McPhearson, T., Baró, F., Madsen, A. L., & Barton, D. N. (2020). Creating urban green infrastructure where it is needed – A spatial ecosystem service-based decision analysis of green roofs in Barcelona. *Science of the Total Environment*, *707*, 135487. https://doi.org/10.1016/j.scitotenv.2019.135487

LaPoint, S., Balkenhol, N., Hale, J., Sadler, J., & van der Ree, R. (2015). Ecological connectivity research in urban areas. *Functional Ecology*, *29*(7), 868–878. https://doi.org/10.1111/1365-2435.12489

Ledsham, T., Farber, S., & Wessel, N. (2017). Dwelling Type Matters: Untangling the Paradox of Intensification and Bicycle Mode Choice. *Transportation Research Record*, *2662*(1), 67–74. https://doi.org/10.3141/2662-08

Lee, A. C. K., Jordan, H. C., & Horsley, J. (2015). Value of urban green spaces in promoting healthy living and wellbeing: Prospects for planning. *Risk Management and Healthcare Policy*, *8*, 131–137. https://doi.org/10.2147/RMHP.S61654

Leffers, D., & Ballamingie, P. (2013). Governmentality, environmental subjectivity, and urban intensification. *Local Environment*, *18*(2), 134–151. https://doi.org/10.1080/13549839.2012.719016

Lehmann, S. (2014). Low carbon districts: Mitigating the urban heat island with green roof infrastructure. *City, Culture and Society*, *5*(1), 1–8. https://doi.org/10.1016/j.ccs.2014.02.002

Lindau, L. A., Hidalgo, D., & de Almeida Lobo, A. (2014). Barriers to planning and implementing Bus Rapid Transit systems. *Research in Transportation Economics*, *48*, 9–15. https://doi.org/10.1016/j.retrec.2014.09.026

Lindberg, F., Grimmond, C. S. B., Gabey, A., Huang, B., Kent, C. W., Sun, T., Theeuwes, N. E., Järvi, L., Ward, H. C., Capel-Timms, I., Chang, Y., Jonsson, P., Krave, N., Liu, D., Meyer, D., Olofson, K. F. G., Tan, J., Wästberg, D., Xue, L., & Zhang, Z. (2018). Urban Multi-scale Environmental Predictor (UMEP): An integrated tool for city-based climate services. *Environmental Modelling and Software*, *99*, 70–87. https://doi.org/10.1016/j.envsoft.2017.09.020

Liu, M., Huang, X., & Xue, G. (2016). Effects of double layer porous asphalt pavement of urban streets on noise reduction. *International Journal of Sustainable Built Environment*, *5*(1), 183–196. https://doi.org/10.1016/j.ijsbe.2016.02.001

Lo, A. Y., & Jim, C. Y. (2010). Willingness of residents to pay and motives for conservation of urban green spaces in the compact city of Hong Kong. *Urban Forestry & Urban Greening*, *9*(2), 113–120.

https://doi.org/10.1016/j.ufug.2010.01.001

Lobaccaro, G., & Frontini, F. (2014). Solar energy in urban environment: How urban densification affects existing buildings. *Energy Procedia*, *48*(1876), 1559–1569. https://doi.org/10.1016/j.egypro.2014.02.176

Loder, A. (2014). "There's a meadow outside my workplace": A phenomenological exploration of aesthetics and green roofs in Chicago and Toronto. *Landscape and Urban Planning*, *126*, 94–106. https://doi.org/10.1016/j.landurbplan.2014.01.008

Lokman, K. (2017). Vacancy as a laboratory: design criteria for reimagining social-ecological systems on vacant urban lands. *Landscape Research*, *42*(7), 728–746. https://doi.org/10.1080/01426397.2017.1355446

Long, J., & Rice, J. L. (2019). From sustainable urbanism to climate urbanism. *Urban Studies*, *56*(5), 992–1008. https://doi.org/10.1177/0042098018770846

Loreau, M., Mouquet, N., & Gonzalez, A. (2003). Biodiversity as spatial insurance in heterogeneous landscapes. *Proceedings of the National Academy of Sciences of the United States of America*, *100*(22), 12765–12770. https://doi.org/10.1073/pnas.2235465100

Lu, Y., Sarkar, C., & Xiao, Y. (2018). The effect of street-level greenery on walking behavior: Evidence from Hong Kong. *Social Science and Medicine*, *208*(December 2017), 41–49. https://doi.org/10.1016/j.socscimed.2018.05.022

Lu, Y., Xiao, Y., & Ye, Y. (2017). Urban density, diversity and design: Is more always better for walking? A study from Hong Kong. *Preventive Medicine*, *103*, S99–S103. https://doi.org/10.1016/j.ypmed.2016.08.042

Lynch, A. J. (2019). Creating Effective Urban Greenways and Stepping-stones: Four Critical Gaps in Habitat Connectivity Planning Research. *Journal of Planning Literature*, *34*(2), 131–155. https://doi.org/10.1177/0885412218798334

Lyytimäki, J., & Sipilä, M. (2009). Hopping on one leg - The challenge of ecosystem disservices for urban green management. *Urban Forestry and Urban Greening*, *8*(4), 309–315. https://doi.org/10.1016/j.ufug.2009.09.003

M-CityCondos. (2023). *Limited, Rogers Real Estate Development*. https://www.mcitycondos.com/construction.php

Madureira, H., Andresen, T., & Monteiro, A. (2011). Green structure and planning evolution in Porto. *Urban Forestry and Urban Greening*, *10*(2), 141–149. https://doi.org/10.1016/j.ufug.2010.12.004

Maes, J., & Jacobs, S. (2017). Nature-Based Solutions for Europe's Sustainable Development. *Conservation Letters*, *10*(1), 121–124. https://doi.org/10.1111/conl.12216

Magle, S. B., Theobald, D. M., & Crooks, K. R. (2009). A comparison of metrics predicting landscape connectivity for a highly interactive species along an urban gradient in Colorado, USA. *Landscape Ecology*, *24*(2), 267–280. https://doi.org/10.1007/s10980-008-9304-x

Mahmoud, I. H. E. H. (2022). From A Highway to A Greenway: A Land Use Dilemma or a Rebirth of a Place? The case of Northend Park, Rose Fitzgerald Kennedy Green Way: Boston, MA, USA.

URBANISTICA INFORMAZIONI, *272*(1), 388–392. https://doi.org/10.2/JQUERY.MIN.JS

Marcucci, D. J., & Jordan, L. M. (2013). Benefits and challenges of linking green infrastructure and highway planning in the United States. *Environmental Management*, *51*(1), 182–197. https://doi.org/10.1007/s00267-012-9966-7

Markham, Ci. of. (2018). *Low Impact Development Series The Markham Municipal Green Road Pilot Project*.

Marshall, A. J., Grose, M. J., & Williams, N. S. G. (2019). Footpaths, tree cut-outs and social contagion drive citizen greening in the road verge. *Urban Forestry and Urban Greening*, *44*(April), 126427. https://doi.org/10.1016/j.ufug.2019.126427

Marzluff, J. (2001). Worldwide urbanization and its effects on birds. In *Avian ecology and conservation in an urbanizing world* (pp. 19–47). https://doi.org/10.1007/978-1-4615-1531-9_2

Masoud, A. R., Idris, A. O., & Lovegrove, G. (2019). Modelling the impact of fused grid network design on mode choice behaviour. *Journal of Transport and Health*, *15*(May), 100627. https://doi.org/10.1016/j.jth.2019.100627

Mathey, J., Arndt, T., Banse, J., & Rink, D. (2018). Public perception of spontaneous vegetation on brownfields in urban areas—Results from surveys in Dresden and Leipzig (Germany). *Urban Forestry and Urban Greening*, *29*, 384–392. https://doi.org/10.1016/j.ufug.2016.10.007

Mathey, J., Rößler, S., Banse, J., Lehmann, I., & Bräuer, A. (2015). Brownfields as an element of green infrastructure for implementing ecosystem services into urban areas. *Journal of Urban Planning and Development*, *141*(3), 1–13. https://doi.org/10.1061/(ASCE)UP.1943-5444.0000275

Matsler, A. M., Meerow, S., Mell, I. C., & Pavao-Zuckerman, M. A. (2021). A 'green' chameleon: Exploring the many disciplinary definitions, goals, and forms of "green infrastructure." *Landscape and Urban Planning*, *214*, 104145. https://doi.org/10.1016/j.landurbplan.2021.104145

McCrea, R., & Walters, P. (2012). Impacts of Urban Consolidation on Urban Liveability: Comparing an Inner and Outer Suburb in Brisbane, Australia. *Housing, Theory and Society*, *29*(2), 190–206. https://doi.org/10.1080/14036096.2011.641261

McFarlane, C. (2016). The geographies of urban density: Topology, politics and the city. *Progress in Human Geography*, *40*(5), 629–648. https://doi.org/10.1177/0309132515608694

McKinney, M. L. (2002). *Urbanization, Biodiversity, and Conservation*. *52*(10).

McPhearson, T., Pickett, S. T. A., Grimm, N. B., Niemelä, J., Alberti, M., Elmqvist, T., Weber, C., Haase, D., Breuste, J., & Qureshi, S. (2016). Advancing Urban Ecology toward a Science of Cities. *BioScience*, *66*(3), 198–212. https://doi.org/10.1093/biosci/biw002

Meerow, S. (2017). Double exposure, infrastructure planning, and urban climate resilience in coastal megacities: A case study of Manila. *Environment and Planning A*, *49*(11), 2649–2672. https://doi.org/10.1177/0308518X17723630

Meerow, S. (2020). The politics of multifunctional green infrastructure planning in New York City. *Cities*, *100*(November 2019), 102621. https://doi.org/10.1016/j.cities.2020.102621

Meerow, S., Natarajan, M., & Krantz, D. (2021). Green infrastructure performance in arid and semi-arid

urban environments. *Urban Water Journal*, *18*(4), 275–285. https://doi.org/10.1080/1573062X.2021.1877741

Mekala, G. D., Jones, R. N., & MacDonald, D. H. (2015). Valuing the Benefits of Creek Rehabilitation: Building a Business Case for Public Investments in Urban Green Infrastructure. *Environmental Management*, *55*(6), 1354–1365. https://doi.org/10.1007/s00267-015-0471-7

Melia, S., Parkhurst, G., & Barton, H. (2011). The paradox of intensification. *Transport Policy*, *18*(1), 46–52. https://doi.org/10.1016/j.tranpol.2010.05.007

Mell, I., & Clement, S. (2019). Progressing Green Infrastructure planning: understanding its scalar, temporal, geo-spatial and disciplinary evolution. *Impact Assessment and Project Appraisal*, *00*(00), 1–15. https://doi.org/10.1080/14615517.2019.1617517

Mesimäki, M., Hauru, K., & Lehvävirta, S. (2019). Do small green roofs have the possibility to offer recreational and experiential benefits in a dense urban area? A case study in Helsinki, Finland. *Urban Forestry and Urban Greening*, *40*, 114–124. https://doi.org/10.1016/j.ufug.2018.10.005

Metrolix (2024). *Hazel McCallion Line work is revitalizing Mary Fix Creek* https://www.metrolinx.com/en/discover/hazel-mccallion-line-work-is-revitalizing-mary-fix-creek

Mexia, T., Vieira, J., Príncipe, A., Anjos, A., Silva, P., Lopes, N., Freitas, C., Santos-Reis, M., Correia, O., Branquinho, C., & Pinho, P. (2018). Ecosystem services: Urban parks under a magnifying glass. *Environmental Research*, *160*(November 2017), 469–478. https://doi.org/10.1016/j.envres.2017.10.023

Meyer, C. K., Strong, R. B., Geerts, J. A., & Bennett, D. (2014). *" Grass " By Any Other Name — Xeriscaping*. *2*(1), 9–22.

Millennium Ecosystem Assessment. (2005). Ecosystems and Human Well-being. *Assessment*, *21*(February), 71–84. http://www.ncbi.nlm.nih.gov/pubmed/12668653

Ministry of Municipal Affairs and Housing. (2019). *A Place to Grow*. https://doi.org/10.1093/geront/25.3.326

Ministry of Municipal Affairs and Housing. (2020a). *Growth Plan for the Greater Golden Horseshoe*. 69–74. https://doi.org/10.2307/j.ctt5hj9n5.9

Ministry of Municipal Affairs and Housing. (2020b). *Provincial Policy Statement, 2020*. *May*, 1–56. ontario.ca/PPS

Mississauga, C. of. (2016). *Mississauga Official Plan, Office Consolidation, Chapter 12 Downtown*. 1–19. http://www6.mississauga.ca/onlinemaps/planbldg/MOP/Chapter12-Downtown.pdf

Mittermüller, J., Erlwein, S., Bauer, A., Trokai, T., Duschinger, S., & Schönemann, M. (2021). Context-Specific, User-Centred: Designing Urban Green Infrastructure to Effectively Mitigate Urban Density and Heat Stress. *Urban Planning*, *6*(4), 40–53. https://doi.org/10.17645/UP.V6I4.4393

Módenes, J. A., & López-Colás, J. (2007). Second homes and compact cities in Spain: Two elements of the same system? *Tijdschrift Voor Economische En Sociale Geografie*, *98*(3), 325–335. https://doi.org/10.1111/j.1467-9663.2007.00400.x

Morakinyo, T. E., & Lam, Y. F. (2016). Study of traffic-related pollutant removal from street canyon with

trees : dispersion and deposition perspective. *Environmental Science and Pollution Research*, 21652–21668. https://doi.org/10.1007/s11356-016-7322-9

Morakinyo, T. E., Lam, Y. F., & Hao, S. (2016). Evaluating the role of green infrastructures on near-road pollutant dispersion and removal: Modelling and measurement. *Journal of Environmental Management*, *182*, 595–605. https://doi.org/10.1016/j.jenvman.2016.07.077

Naumann, S., Rayment, M., Nolan, P., Forest, T. M., Gill, S., Infrastructure, G., & Forest, M. (2011). *Design, implementation and cost elements of Green Infrastructure projects. Final Report*. *070307*.

Newell, J. P., Seymour, M., Yee, T., Renteria, J., Longcore, T., Wolch, J. R., & Shishkovsky, A. (2013). Green Alley Programs: Planning for a sustainable urban infrastructure? *Cities*, *31*, 144–155. https://doi.org/10.1016/j.cities.2012.07.004

Nickel, D., Schoenfelder, W., Medearis, D., Dolowitz, D. P., Keeley, M., & Shuster, W. (2014). German experience in managing stormwater with green infrastructure. *Journal of Environmental Planning and Management*, *57*(3), 403–423. https://doi.org/10.1080/09640568.2012.748652

Nilon, C. H., Aronson, M. F. J., Cilliers, S. S., Dobbs, C., Frazee, L. J., Goddard, M. A., O'Neill, K. M., Roberts, D., Stander, E. K., Werner, P., Winter, M., & Yocom, K. P. (2017). Planning for the future of urban biodiversity: A global review of city-scale initiatives. *BioScience*, *67*(4), 332–342. https://doi.org/10.1093/biosci/bix012

Nolon, J. R. (2016). Enhancing the Urban Environment Through Green Infrastructure. *Environmental Law Reporter*, *46*, 10071–10086. http://ssrn.com/abstract=2724050

Norton, B. A., Coutts, A. M., Livesley, S. J., Harris, R. J., Hunter, A. M., & Williams, N. S. G. G. (2015). Planning for cooler cities: A framework to prioritise green infrastructure to mitigate high temperatures in urban landscapes. *Landscape and Urban Planning*, *134*, 127–138. https://doi.org/10.1016/j.landurbplan.2014.10.018

Novak, M. (2019). Assessing the long-term performance of the urban cores in four New Urbanist communities. *Journal of Urban Design*, *24*(3), 368–384. https://doi.org/10.1080/13574809.2019.1568186

Nowak, D. J., Hirabayashi, S., Doyle, M., McGovern, M., & Pasher, J. (2018). Air pollution removal by urban forests in Canada and its effect on air quality and human health. *Urban Forestry and Urban Greening*, *29*(November 2017), 40–48. https://doi.org/10.1016/j.ufug.2017.10.019

O'Sullivan, O. S., Holt, A. R., Warren, P. H., & Evans, K. L. (2017). Optimising UK urban road verge contributions to biodiversity and ecosystem services with cost-effective management. *Journal of Environmental Management*, *191*, 162–171. https://doi.org/10.1016/j.jenvman.2016.12.062

Owen, D. (2004). Green Manhattan. *The New Yorker*, *80*, 111.

Pamučar, D., Gigović, L., Ćirović, G., & Regodić, M. (2016). Transport spatial model for the definition of green routes for city logistics centers. *Environmental Impact Assessment Review*, *56*, 72–87. https://doi.org/10.1016/j.eiar.2015.09.002

Panagopoulos, T. (2019). Special Issue: Landscape Urbanism and Green Infrastructure. *Land*, *8*(7), 112. https://doi.org/10.3390/land8070112

Pataki, D. E., Carreiro, M. M., Cherrier, J., Grulke, N. E., Jennings, V., Pincetl, S., Pouyat, R. V., Whitlow, T. H., & Zipperer, W. C. (2011). Coupling biogeochemical cycles in urban environments: ecosystem services, green solutions, and misconceptions. *Frontiers in Ecology and the Environment*, *9*(1), 27–36. https://doi.org/10.1890/090220

Pauleit, S., Ambrose-Oji, B., Andersson, E., Anton, B., Buijs, A., Haase, D., Elands, B., Hansen, R., Kowarik, I., Kronenberg, J., Mattijssen, T., Stahl Olafsson, A., Rall, E., van der Jagt, A. P. N., & Konijnendijk van den Bosch, C. (2019). Advancing urban green infrastructure in Europe: Outcomes and reflections from the GREEN SURGE project. *Urban Forestry and Urban Greening*, *40*(October 2018), 4–16. https://doi.org/10.1016/j.ufug.2018.10.006

Penone, C., Machon, N., Julliard, R., & Le Viol, I. (2012). Do railway edges provide functional connectivity for plant communities in an urban context? *Biological Conservation*, *148*(1), 126–133. https://doi.org/10.1016/j.biocon.2012.01.041

Pérez, G., Coma, J., Barreneche, C., De Gracia, A., Urrestarazu, M., Burés, S., & Cabeza, L. F. (2016). Acoustic insulation capacity of Vertical Greenery Systems for buildings. *Applied Acoustics*, *110*, 218–226. https://doi.org/10.1016/j.apacoust.2016.03.040

Pérez, G., Coma, J., Martorell, I., & Cabeza, L. F. (2014). Vertical Greenery Systems (VGS) for energy saving in buildings: A review. *Renewable and Sustainable Energy Reviews*, *39*, 139–165. https://doi.org/10.1016/j.rser.2014.07.055

Perrott, K. (2020). Does new urbanism "just show up"? Deliberate process and the evolving plan for markham centre. *Urban Planning*, *5*(4), 388–403. https://doi.org/10.17645/UP.V5I4.3543

Plieninger, T., Dijks, S., Oteros-Rozas, E., & Bieling, C. (2013). Assessing, mapping, and quantifying cultural ecosystem services at community level. *Land Use Policy*, *33*, 118–129. https://doi.org/10.1016/j.landusepol.2012.12.013

Potgieter, L. J., Gaertner, M., O'Farrell, P. J., & Richardson, D. M. (2019). A fine-scale assessment of the ecosystem service-disservice dichotomy in the context of urban ecosystems affected by alien plant invasions. *Forest Ecosystems*, *6*(1), 1–16. https://doi.org/10.1186/s40663-019-0200-4

Pugh, T. A. M. M., MacKenzie, A. R., Whyatt, J. D., & Hewitt, C. N. (2012). Effectiveness of Green Infrastructure for Improvement of Air Quality in Urban Street Canyons. *Environmental Science and Technology*, *46*(14), 7692–7699. https://doi.org/10.1021/es300826w

Puppim de Oliveira, J. A., Bellezoni, R. A., Shih, W. yu, & Bayulken, B. (2022). Innovations in Urban Green and Blue Infrastructure: Tackling local and global challenges in cities. *Journal of Cleaner Production*, *362*(May), 132355. https://doi.org/10.1016/j.jclepro.2022.132355

Quintas-Soriano, C., García-Llorente, M., Norström, A., Meacham, M., Peterson, G., & Castro, A. J. (2019). Integrating supply and demand in ecosystem service bundles characterization across Mediterranean transformed landscapes. *Landscape Ecology*, *34*(7), 1619–1633. https://doi.org/10.1007/s10980-019-00826-7

Radall, T., & Beatz, B. (2001). *EVALUATING PEDESTRIAN CONNECTIVITY FOR SUBURBAN SUSTAINABILITY*. *127*(1), 1–15.

Rai, A., Minsker, B., Sullivan, W., & Band, L. (2019). A novel computational green infrastructure design

framework for hydrologic and human benefits. *Environmental Modelling and Software*, *118*(January), 252–261. https://doi.org/10.1016/j.envsoft.2019.03.016

Raman, R., & Roy, U. K. (2019). Taxonomy of urban mixed land use planning. *Land Use Policy*, *88*(June), 104102. https://doi.org/10.1016/j.landusepol.2019.104102

Ramyar, R., Ramyar, A., Kialashaki, Y., Bryant, M., & Ramyar, H. (2019). Exploring reconfiguration scenarios of high-density urban neighborhoods on urban temperature–The case of Tehran (Iran). *Urban Forestry and Urban Greening*, *44*(February), 126398. https://doi.org/10.1016/j.ufug.2019.126398

Ramyar, R., Saeedi, S., Bryant, M., Davatgar, A., & Mortaz Hedjri, G. (2020). Ecosystem services mapping for green infrastructure planning–The case of Tehran. *Science of the Total Environment*, *703*, 135466. https://doi.org/10.1016/j.scitotenv.2019.135466

Rashid, M., & Ara, D. R. (2019). Bringing design back: resetting liveability of a 'near but not in the city' housing environment in Sydney. *Journal of Urban Design*, *24*(2), 210–231. https://doi.org/10.1080/13574809.2018.1440175

Rembeza, M. (2017). Integrating Art into Places in Transition - Rose Kennedy Greenway in Boston as a Case Study. *IOP Conference Series: Materials Science and Engineering*, *245*, 052070. https://doi.org/10.1088/1757-899X/245/5/052070

Revell, G., & Anda, M. (2014). Sustainable Urban biophilia: The case of greenskins for Urban density. *Sustainability (Switzerland)*, *6*(8), 5423–5438. https://doi.org/10.3390/su6085423

Rey, E., & Lufkin, S. (2016). A transdisciplinary research and teaching project for the design of sustainable neighbourhoods. *GAIA*, *25*(3), 185–190. https://doi.org/10.14512/gaia.25.3.10

Rising, H. H. (2019). The image of the water city. *Journal of Urban Design*, *24*(3), 424–442. https://doi.org/10.1080/13574809.2018.1480362

Rodríguez, D. A., Aytur, S., Forsyth, A., Oakes, J. M., & Clifton, K. J. (2008). Relation of modifiable neighborhood attributes to walking. *Preventive Medicine*, *47*(3), 260–264. https://doi.org/10.1016/j.ypmed.2008.02.028

Roman, L. A., Conway, T. M., Eisenman, T. S., Koeser, A. K., Ordóñez Barona, C., Locke, D. H., Jenerette, G. D., Östberg, J., & Vogt, J. (2021). Beyond 'trees are good': Disservices, management costs, and tradeoffs in urban forestry. *Ambio*, *50*(3), 615–630. https://doi.org/10.1007/s13280-020-01396-8

Ronchi, S., Arcidiacono, A., & Pogliani, L. (2020). Integrating green infrastructure into spatial planning regulations to improve the performance of urban ecosystems. Insights from an Italian case study. *Sustainable Cities and Society*, *53*(April 2019), 101907. https://doi.org/10.1016/j.scs.2019.101907

Rossetti, T., Lobel, H., Rocco, V., & Hurtubia, R. (2019). Explaining subjective perceptions of public spaces as a function of the built environment: A massive data approach. *Landscape and Urban Planning*, *181*(October 2018), 169–178. https://doi.org/10.1016/j.landurbplan.2018.09.020

Rusche, K., Reimer, M., & Stichmann, R. (2019). Mapping and assessing green infrastructure connectivity in European city regions. *Sustainability (Switzerland)*, *11*(6). https://doi.org/10.3390/SU11061819

Ryan, S., & Frank, L. (2009). Pedestrian Environments and Transit Ridership. *Journal of Public Transportation*, *12*(1), 39–57. https://doi.org/10.5038/2375-0901.12.1.3

Saaroni, H., Amorim, J. H., Hiemstra, J. A., & Pearlmutter, D. (2018). *Urban Climate Urban Green Infrastructure as a tool for urban heat mitigation : Survey of research methodologies and fi ndings across di ff erent climatic regions*. *24*(February), 94–110.

Saboonian, S. (2014). *The Relationship between Policy, Program, and Implementation in Sustainable Urban Water Management* [University of Minnesota]. https://hdl.handle.net/11299/191225

Saboonian, S., & Filion, P. (2019). Recentralization and Green Infrastructures: Seeking Compatibility between Alternatives to North American Suburban Development. In P. Filion & N. Pulver (Eds.), *Critical Perspectives on Suburban Infrastructures, Contemporary Intenational Cases*. University of Toronto Press.

Saidla, K. (2018). Health promotion by stealth: active transportation success in Helsinki, Finland. *Health Promotion International*, *33*(4), 600–609. https://doi.org/10.1093/heapro/daw110

Salata, K., & Yiannakou, A. (2016). Green Infrastructure and climate change adaptation. *TeMA, Vol 9*, 7–24. https://doi.org/1970-9870/3723

Sansalone, J., Raje, S., Kertesz, R., Maccarone, K., Seltzer, K., Siminari, M., Simms, P., & Wood, B. (2013). Retrofitting impervious urban infrastructure with green technology for rainfall-runoff restoration, indirect reuse and pollution load reduction. *Environmental Pollution*, *183*, 204–212. https://doi.org/10.1016/j.envpol.2013.01.051

Säumel, I., Weber, F., & Kowarik, I. (2016). Toward livable and healthy urban streets: Roadside vegetation provides ecosystem services where people live and move. *Environmental Science and Policy*, *62*, 24–33. https://doi.org/10.1016/j.envsci.2015.11.012

Savvides, A., Vassiliades, C., Michael, A., & Kalogirou, S. (2019). Siting and building-massing considerations for the urban integration of active solar energy systems. *Renewable Energy*, *135*(2019), 963–974. https://doi.org/10.1016/j.renene.2018.12.017

Schäffler, A., & Swilling, M. (2013). Valuing green infrastructure in an urban environment under pressure - The Johannesburg case. *Ecological Economics*, *86*, 246–257. https://doi.org/10.1016/j.ecolecon.2012.05.008

Schollen & Company Inc. (2022). ***済無****No Title No Title No Title*. https://schollenandcompany.com/

Schubert, J. E., Burns, M. J., Fletcher, T. D., & Sanders, B. F. (2017). A framework for the case-specific assessment of Green Infrastructure in mitigating urban flood hazards. *Advances in Water Resources*, *108*, 55–68. https://doi.org/10.1016/j.advwatres.2017.07.009

Schwarz, T. (2012). Urban Design and Stormwater Management Strategies for Suburban Regeneration. *SSRN Electronic Journal*, 1–11. https://doi.org/10.2139/ssrn.2016932

Searle, G., & Filion, P. (2011). Planning context and Urban intensification outcomes: Sydney versus Toronto. *Urban Studies*, *48*(7), 1419–1438. https://doi.org/10.1177/0042098010375995

Semeraro, T., Aretano, R., Barca, A., Pomes, A., Del Giudice, C., Gatto, E., Lenucci, M., Buccolieri, R., Emmanuel, R., Gao, Z., & Scognamiglio, A. (2020). A conceptual framework to design green

infrastructure: Ecosystem services as an opportunity for creating shared value in ground photovoltaic systems. *Land*, *9*(8). https://doi.org/10.4054/DEMRES.2020.43.9

Shao, Z., Sumari, N. S., Portnov, A., Ujoh, F., Musakwa, W., & Mandela, P. J. (2021). Urban sprawl and its impact on sustainable urban development: a combination of remote sensing and social media data. *Geo-Spatial Information Science*, *24*(2), 241–255. https://doi.org/10.1080/10095020.2020.1787800

Shi, X., Qin, M., Li, B., & Zhang, D. (2021). A framework for optimizing green infrastructure networks based on landscape connectivity and ecosystem services. *Sustainability (Switzerland)*, *13*(18). https://doi.org/10.3390/su131810053

Sikorski, P., Wińska-Krysiak, M., Chormański, J., Krauze, K., Kubacka, K., Sikorska, D., Wi, M., & Krauze, K. (2018). Low-maintenance green tram tracks as a socially acceptable solution to greening a city. *Urban Forestry and Urban Greening*, *35*(May), 148–164. https://doi.org/10.1016/j.ufug.2018.08.017

Silva, C. de S., Viegas, I., Panagopoulos, T., & Bell, S. (2018). Environmental justice in accessibility to green infrastructure in two European Cities. *Land*, *7*(4). https://doi.org/10.3390/land7040134

Simpson, L. B. (2011). *Dancing on our turtle's back: Stories of Nishnaabeg re-creation, resurgence and a new emergence*. Winnipeg, MB, Canada: Arbeiter Ring Pub.

Snäll, T., Lehtomäki, J., Arponen, A., Elith, J., & Moilanen, A. (2016). Green Infrastructure Design Based on Spatial Conservation Prioritization and Modeling of Biodiversity Features and Ecosystem Services. *Environmental Management*, *57*(2), 251–256. https://doi.org/10.1007/s00267-015-0613-y

Spatari, S., Yu, Z., & Montalto, F. A. (2011). Life cycle implications of urban green infrastructure. *Environmental Pollution*, *159*(8–9), 2174–2179. https://doi.org/10.1016/j.envpol.2011.01.015

Sprouse, C. E., Hoover, C., Obritsch, O., & Thomazin, H. (2020). Advancing pervious pavements through nomenclature, standards, and holistic green design. *Sustainability (Switzerland)*, *12*(18). https://doi.org/10.3390/SU12187422

Staccione, A., Candiago, S., & Mysiak, J. (2022). Mapping a Green Infrastructure Network: a framework for spatial connectivity applied in Northern Italy. *Environmental Science and Policy*, *131*, 57–67. https://doi.org/10.1016/j.envsci.2022.01.017

Strohbach, M. W., & Haase, D. (2012). Above-ground carbon storage by urban trees in Leipzig, Germany: Analysis of patterns in a European city. *Landscape and Urban Planning*, *104*(1), 95–104. https://doi.org/10.1016/j.landurbplan.2011.10.001

Strohbach, M. W., Lerman, S. B., & Warren, P. S. (2013). Are small greening areas enhancing bird diversity? Insights from community-driven greening projects in Boston. *Landscape and Urban Planning*, *114*, 69–79. https://doi.org/10.1016/j.landurbplan.2013.02.007

Suppakittpaisarn, P., Jiang, B., Slavenas, M., & Sullivan, W. C. (2019). Does density of green infrastructure predict preference? *Urban Forestry and Urban Greening*, *40*(October 2017), 236–244. https://doi.org/10.1016/j.ufug.2018.02.007

Surtees, R. (1985). Indian Land Surrenders in Ontario. Research Branch, Indian and Northern Affairs Canada.

Sussams, L. W., Sheate, W. R., & Eales, R. P. (2015). Green infrastructure as a climate change adaptation policy intervention: Muddying the waters or clearing a path to a more secure future? *Journal of Environmental Management*, *147*, 184–193. https://doi.org/10.1016/j.jenvman.2014.09.003

Szulczewska, B., Giedych, R., & Maksymiuk, G. (2017). Can we face the challenge: how to implement a theoretical concept of green infrastructure into planning practice? Warsaw case study. *Landscape Research*, *42*(2), 176–194. https://doi.org/10.1080/01426397.2016.1240764

Tamminga, K., Cortesão, J., & Bakx, M. (2020). Convivial greenstreets: A concept for climate-responsive urban design. *Sustainability (Switzerland)*, *12*(9). https://doi.org/10.3390/su12093790

Tan, P. Y., Wang, J., & Sia, A. (2013). Perspectives on five decades of the urban greening of Singapore. *Cities*, *32*, 24–32. https://doi.org/10.1016/J.CITIES.2013.02.001

Tandarić, N., Ives, C. D., & Watkins, C. (2020). Can we plan for urban cultural ecosystem services? *Journal of Urban Ecology*, *6*(1), 1–17. https://doi.org/10.1093/jue/juaa016

Tappert, S., Klöti, T., & Drilling, M. (2018). Contested urban green spaces in the compact city: The (re-)negotiation of urban gardening in Swiss cities. *Landscape and Urban Planning*, *170*(April 2016), 69–78. https://doi.org/10.1016/j.landurbplan.2017.08.016

Teaford, J. C., Schuyler, D., & Cutler, P. (1987). *Review : Landscaping America Reviewed Work (s): The New Urban Landscape : The Redefinition of City Form in Nineteenth-Century America by David Schuyler ; The Public Landscape of the New Deal by Phoebe Cutler Review by : Jon C . Teaford Source : Reviews*. http://www.jstor.org/stable/pdf/2701945.pdf

TEEB. (2011). TEEB Manual for Cities : Ecosystem Services in Urban Management. In *The Economics of Ecosystems and Biodiversity*.

Thiagarajan, M., Newman, G., & Van Zandt, S. (2018). The projected impact of a neighborhood-scaled green-infrastructure retrofit. *Sustainability (Switzerland)*, *10*(10). https://doi.org/10.3390/su10103665

Thompson, K., Sherren, K., & Duinker, P. N. (2019). The use of ecosystem services concepts in Canadian municipal plans. *Ecosystem Services*, *38*(July 2018), 100950. https://doi.org/10.1016/j.ecoser.2019.100950

Tian, Yuhong, Jim, C. Y., & Tao, Y. (2012). Challenges and Strategies for Greening the Compact City of Hong Kong. *Journal of Urban Planning and Development*, *138*(2), 101–109. https://doi.org/10.1061/(ASCE)UP.1943-5444.0000076.

Tian, Yuqing, Wu, H., Zhang, G., Wang, L., Zheng, D., & Li, S. (2020). Perceptions of ecosystem services, disservices and willingness-to-pay for urban green space conservation. *Journal of Environmental Management*, *260*(December 2019), 110140. https://doi.org/10.1016/j.jenvman.2020.110140

Tillie, N., Borsboom-van Beurden, J., Doepel, D., & Aarts, M. (2018). Exploring a stakeholder based urban densification and greening agenda for rotterdam inner city-accelerating the transition to a liveable low carbon city. *Sustainability (Switzerland)*, *10*(6). https://doi.org/10.3390/su10061927

Tiwary, A., & Kumar, P. (2014). Impact evaluation of green-grey infrastructure interaction on built-space integrity: An emerging perspective to urban ecosystem service. *Science of the Total Environment*,

487(1), 350–360. https://doi.org/10.1016/j.scitotenv.2014.03.032

Tomson, M., Kumar, P., Barwise, Y., Perez, P., Forehead, H., French, K., Morawska, L., & Watts, J. F. (2021). Green infrastructure for air quality improvement in street canyons. *Environment International*, *146*(December 2020), 106288. https://doi.org/10.1016/j.envint.2020.106288

Tratalos, J., Fuller, R. A., Warren, P. H., Davies, R. G., & Gaston, K. J. (2007). Urban form, biodiversity potential and ecosystem services. *Landscape and Urban Planning*, *83*(4), 308–317. https://doi.org/10.1016/j.landurbplan.2007.05.003

Truth, & Reconciliation Commission of Canada. (2015). *Final Report of the Truth and Reconciliation Commission of Canada, Volume One: Summary: Honouring the Truth, Reconciling for the Future*. James Lorimer & Company.

Tsai, W. L., Yngve, L., Zhou, Y., Beyer, K. M. M., Bersch, A., Malecki, K. M., & Jackson, L. E. (2019). Street-level neighborhood greenery linked to active transportation: A case study in Milwaukee and Green Bay, WI, USA. *Landscape and Urban Planning*, *191*(July), 103619. https://doi.org/10.1016/j.landurbplan.2019.103619

Tsegaye, S., Singleton, T. L., Koeser, A. K., Lamb, D. S., Landry, S. M., Lu, S., Barber, J. B., Hilbert, D. R., Hamilton, K. O., Northrop, R. J., & Ghebremichael, K. (2019). Transitioning from gray to green (G2G)—A green infrastructure planning tool for the urban forest. *Urban Forestry and Urban Greening*, *40*(September 2018), 204–214. https://doi.org/10.1016/j.ufug.2018.09.005

Tsigdinos, S., & Vlastos, T. (2020). Strategic road network formulation: Developing an alternative methodology towards sustainable mobility. *Transportation Research Procedia*, *47*(2019), 505–512. https://doi.org/10.1016/j.trpro.2020.03.125

Turner, N. J. (2008). *The earth's blanket: Traditional teachings for sustainable living*. D & M Publishers.

Turner, T. (1995). Greenways, blueways, skyways and other ways to a better London. *Landscape and Urban Planning*, *33*(1–3), 269–282.

Tzoulas, K., Korpela, K., Venn, S., Yli-Pelkonen, V., Kaźmierczak, A., Niemela, J., & James, P. (2007). Promoting ecosystem and human health in urban areas using Green Infrastructure: A literature review. *Landscape and Urban Planning*, *81*(3), 167–178. https://doi.org/10.1016/j.landurbplan.2007.02.001

Unt, A. L., & Bell, S. (2014). The impact of small-scale design interventions on the behaviour patterns of the users of an urban wasteland. *Urban Forestry and Urban Greening*, *13*(1), 121–135. https://doi.org/10.1016/j.ufug.2013.10.008

Van Teeffelen, A. J. A., Vos, C. C., Jochem, R., Baveco, J. M., Meeuwsen, H., & Hilbers, J. P. (2015). Is green infrastructure an effective climate adaptation strategy for conserving biodiversity? A case study with the great crested newt. *Landscape Ecology*, *30*(5), 937–954. https://doi.org/10.1007/s10980-015-0187-3

Vargas-Hernández, J. G., & Zdunek-Wielgołaska, J. (2021). Urban green infrastructure as a tool for controlling the resilience of urban sprawl. *Environment, Development and Sustainability*, *23*(2), 1335–1354. https://doi.org/10.1007/s10668-020-00623-2

Vecchio, M., & Arku, G. (2020). Promoting adaptive reuse in Ontario: A planning policy tool for making

the best of manufacturing decline. *Urban Planning*, *5*(3), 338–350. https://doi.org/10.17645/up.v5i3.3188

Veitch, J., Salmon, J., Ball, K., Crawford, D., & Timperio, A. (2013). Do features of public open spaces vary between urban and rural areas? *Preventive Medicine*, *56*(2), 107–111. https://doi.org/10.1016/j.ypmed.2012.11.016

Venter, Z. S., Barton, D. N., Gundersen, V., Figari, H., & Nowell, M. (2020). *Urban nature in a time of crisis: recreational use of green space increases during the COVID-19 outbreak in Oslo, Norway*. 1–23. http://senseable.mit.edu/treepedia/cities/oslo

Verhoeven, H., Ghekiere, A., Van Cauwenberg, J., Van Dyck, D., De Bourdeaudhuij, I., Clarys, P., & Deforche, B. (2017). Which physical and social environmental factors are most important for adolescents' cycling for transport? An experimental study using manipulated photographs. *International Journal of Behavioral Nutrition and Physical Activity*, *14*(1), 1–13. https://doi.org/10.1186/s12966-017-0566-z

Voter, C. B., & Loheide, S. P. (2018). Urban Residential Surface and Subsurface Hydrology: Synergistic Effects of Low-Impact Features at the Parcel Scale. *Water Resources Research*, *54*(10), 8216–8233. https://doi.org/10.1029/2018WR022534

Walmsley, A. (1995). Greenways and the making of urban form. *Landscape and Urban Planning*, *33*(1–3), 81–127.

Walmsley, A. (2006). Greenways: multiplying and diversifying in the 21st century. *Landscape and Urban Planning*, *76*(1–4), 252–290. https://doi.org/10.1016/j.landurbplan.2004.09.036

Wang, Yafei, Bakker, F., de Groot, R., W??rtche, H., & Wörtche, H. (2014). Effect of ecosystem services provided by urban green infrastructure on indoor environment: A literature review. *Building and Environment*, *77*, 88–100. https://doi.org/10.1016/j.buildenv.2014.03.021

Wang, Yupeng, Berardi, U., & Akbari, H. (2016). Comparing the effects of urban heat island mitigation strategies for Toronto, Canada. *Energy and Buildings*, *114*, 2–19. https://doi.org/10.1016/j.enbuild.2015.06.046

Ward, H. C., Kotthaus, S., Grimmond, C. S. B., Bjorkegren, A., Wilkinson, M., Morrison, W. T. J., Evans, J. G., Morison, J. I. L., & Iamarino, M. (2015). Effects of urban density on carbon dioxide exchanges: Observations of dense urban, suburban and woodland areas of southern England. *Environmental Pollution*, *198*, 186–200. https://doi.org/10.1016/j.envpol.2014.12.031

Weber, F., Kowarik, I., & Säumel, I. (2014). A walk on the wild side: Perceptions of roadside vegetation beyond trees. *Urban Forestry and Urban Greening*, *13*(2), 205–212. https://doi.org/10.1016/j.ufug.2013.10.010

Wheeler, S. M. (2000). Planning for metropolitan sustainability. *Journal of Planning Education and Research*, *20*(2), 133–145. https://doi.org/10.1177/0739456X0002000201

Williams, K. (2004). Can Urban Intensification Contribute to Sustainable Cities ? An International Perspective. *City Matters: Official Electronic Journal of Urbanicity*.

Wise, S., Braden, J., Ghalayini, D., Grant, J., Kloss, C., Macmullan, E., Morse, S., Montalto, F., Nees, D., Nowak, D., Peck, S., Shaikh, S., & Yu, C. (2010). Integrating Valuation Methods to Recognize

Green Infrastructure's Multiple Benefits. In *Low impact development 2010: Redefining water in the city* (pp. 1123–1143).

Wise, S., Braden, J., Ghalayini, D., Grant, J., Kloss, C., MacMullan, E., Morse, S., Montalto, F., Nees, D., Nowak, D., Peck, S., Shaikh, S., & Yu, C. (2010). Integrating Valuation Methods to Recognize Green Infrastructure's Multiple Benefits. *Low Impact Development 2010*, 1123–1143. https://doi.org/10.1061/41099(367)98

Wolch, J. R., Byrne, J., & Newell, J. P. (2014). Urban green space, public health, and environmental justice: The challenge of making cities "just green enough." *Landscape and Urban Planning*, *125*, 234–244. https://doi.org/10.1016/j.landurbplan.2014.01.017

World Wildlife Fund Canada. (2022). *Urban Biodiversity*. https://wwf.ca/habitat/urban-areas/

Woznicki, S. A., Hondula, K. L., & Jarnagin, S. T. (2018). Effectiveness of landscape-based green infrastructure for stormwater management in suburban catchments. *Hydrological Processes*, *32*(15), 2346–2361. https://doi.org/10.1002/hyp.13144

Wright, H. (2011). Understanding green infrastructure: the development of a contested concept in England. *Local Environment*, *16*(10), 1003–1019. https://doi.org/10.1080/13549839.2011.631993

Wright Wendel, H. E., Zarger, R. K., & Mihelcic, J. R. (2012). Accessibility and usability: Green space preferences, perceptions, and barriers in a rapidly urbanizing city in Latin America. *Landscape and Urban Planning*, *107*(3), 272–282. https://doi.org/10.1016/j.landurbplan.2012.06.003

Wu, Z., & Zhang, Y. (2019). Water bodies' cooling effects on urban land daytime surface temperature: Ecosystem service reducing heat island effect. *Sustainability (Switzerland)*, *11*(3), 1–11. https://doi.org/10.3390/su11030787

Xu, J. L. (2017). Is New Urbanism changing the suburban development pattern? A case study of the Toronto region. *Journal of Urban Design*, *22*(6), 812–832. https://doi.org/10.1080/13574809.2017.1337494

Yan, L., & Zhou, W. (2016). *Innovation and Reflection on Peter Calthorpe ' s New Urbanism*. *I3csee*, 29–34.

Yang, J., Shi, B., Shi, Y., Marvin, S., Zheng, Y., & Xia, G. (2020). Air pollution dispersal in high density urban areas: Research on the triadic relation of wind, air pollution, and urban form. *Sustainable Cities and Society*, *54*(July 2019), 101941. https://doi.org/10.1016/j.scs.2019.101941

York University. (2022). *York University Markham Campus*. https://www.yorku.ca/markham/

Young, R. F., & McPherson, E. G. (2013). Governing metropolitan green infrastructure in the United States. *Landscape and Urban Planning*, *109*(1), 67–75. https://doi.org/10.1016/j.landurbplan.2012.09.004

Zagorskas, J. (2016). GIS-based Modelling and Estimation of Land Use Mix in Urban Environment 2 Problem Formulation. *International Journal of Environmental Science*, *1*, 284–293.

Zaimes, G. N., & Iakovoglou, V. (2021). Assessing riparian areas of Greece-an overview. *Sustainability (Switzerland)*, *13*(1), 1–19. https://doi.org/10.3390/su13010309

Zhang, Z., Meerow, S., Newell, J. P., & Lindquist, M. (2019). Enhancing landscape connectivity through

multifunctional green infrastructure corridor modeling and design. *Urban Forestry and Urban Greening*, *38*(July 2018), 305–317. https://doi.org/10.1016/j.ufug.2018.10.014

Zölch, T., Maderspacher, J., Wamsler, C., & Pauleit, S. (2016). Urban Forestry & Urban Greening Using green infrastructure for urban climate-proofing : An evaluation of heat mitigation measures at the micro-scale. *Urban Forestry & Urban Greening*, *20*, 305–316. https://doi.org/10.1016/j.ufug.2016.09.011

Zuniga-Teran, A. A., Staddon, C., de Vito, L., Gerlak, A. K., Ward, S., Schoeman, Y., Hart, A., & Booth, G. (2020). Challenges of mainstreaming green infrastructure in built environment professions. *Journal of Environmental Planning and Management*, *63*(4), 710–732. https://doi.org/10.1080/09640568.2019.1605890

Zwierzchowska, I., Hof, A., Iojă, I. C., Mueller, C., Poniży, L., Breuste, J., & Mizgajski, A. (2018). Multi-scale assessment of cultural ecosystem services of parks in Central European cities. *Urban Forestry and Urban Greening*, *30*, 84–97. https://doi.org/10.1016/j.ufug.2017.12.017

Appendix A

Glossary of Terms

Term	Description
Active Transportation	Modes of transportation that involve physical activity, such as walking, cycling, and skating.
Assessment Framework	A structured method or tool used to evaluate and measure the performance of specific characteristics or elements within a system.
Biodiversity	The variety of life forms and ecosystems present in a particular area, including the genetic, species, and ecosystem diversity.
Biodiversity Corridors	Strips or pathways of natural habitats connecting fragmented ecosystems, facilitating the movement of plant and animal species.
Bioswale	A landscape feature designed to manage stormwater runoff, typically a vegetated, shallow ditch or depression.
Combined Sewer Overflow (CSO)	The release of untreated or partially treated sewage and stormwater from a combined sewer system during heavy rainfall events.
Compact City	An urban development model promoting higher population densities and mixed land uses to reduce urban sprawl and increase efficiency.
Connectivity	Physical and functional connections between urban elements, such as green spaces and transportation networks, at different scales and from different perspectives.
Cul-de-sac	A dead-end street with only one entrance and exit point, typically designed for limited through-traffic.
Design Guidelines	Specific recommendations and principles provided to guide the design and development of urban spaces.
Ecological Corridors	Linear areas that connect habitat patches, enabling the movement of species and ecological processes.
Ecological Networks	Interconnected networks of natural and semi-natural areas that support biodiversity conservation and ecosystem functioning.
Ecosystem Services	The benefits that humans derive from ecosystems, including provisioning services (e.g., food, water), regulating services (e.g., climate regulation, water purification), supporting services (e.g., nutrient cycling), and cultural services (e.g., recreational and aesthetic benefits).
Environmental Education	Initiatives and programs that aim to raise awareness and understanding of environmental issues and promote sustainable behavior.
Environmental Impact Assessment (EIA)	A process that evaluates the potential environmental effects of a proposed development project or policy and provides measures to mitigate negative impacts.
Functional Connectivity	The actual movement of species and ecological processes facilitated by the physical connections between landscape elements.
Geographic Information System (GIS)	A system designed to capture, store, analyze, manage, and present spatial or geographic data.
Green Building	A structure designed to be environmentally friendly and resource-efficient throughout its lifecycle.

Green Infrastructure (GI)	A network of natural and semi-natural spaces, features, and systems, such as parks, green spaces, wetlands, and green roofs in urban areas.
Green Roof	A vegetated roof system that involves growing plants on the rooftop of a building, providing multiple benefits.
Green Wall	A vertical garden or living wall composed of vegetation grown on a building's exterior surface.
Greenbelt	An area of protected or undeveloped land surrounding an urban area to prevent urban sprawl and protect natural habitats and agricultural lands.
Greenfield Development	The construction and development of new buildings and infrastructure on previously undeveloped or agricultural land.
Grey Infrastructure	Traditional, engineered infrastructure like roads and buildings, contrasting with green infrastructure in terms of natural features.
Grid-Like Street Pattern	A street layout characterized by a network of interconnected and perpendicular streets, forming a grid pattern.
Habitat Patches	Discrete areas of habitat that support specific plant and animal species.
Intensification	The process of increasing the density and diversity of the built environment in urban areas, often implemented as a solution to urban sprawl.
Infill Development	The development of vacant or underutilized land within existing urban areas, usually through the construction of new buildings or redevelopment of existing structures.
Leadership in Energy and Environmental Design (LEED)	A rating system for assessing the environmental performance of buildings and neighborhoods, focusing on sustainability and energy efficiency.
Low Impact Development (LID)	An approach to urban development that aims to manage stormwater runoff at the source, using green infrastructure techniques and nature-based solutions to reduce its impact on urban areas.
Landscape Ecology	The study of the spatial patterns and relationships of ecological processes within landscapes.
Meta-analysis	A research method that combines data from multiple studies to draw general conclusions or identify trends.
Mixed-Use Development	An urban planning concept that integrates a mix of residential, commercial, and recreational uses within the same area.
Multifunctionality	The ability of a space or system to serve multiple purposes or provide multiple benefits in urban planning.
Nature-based Solutions	Design approaches that intentionally use natural processes and elements to address environmental and urban challenges.
New Urbanism	A planning and development approach focused on creating compact, walkable communities with mixed land uses.
Open Space Networks	Connected areas of natural or green spaces within urban environments that provide recreational opportunities and support biodiversity.
Pedestrian-Friendly Design	Urban design that prioritizes and accommodates pedestrians by creating safe and attractive walking environments with amenities like sidewalks, crosswalks, and pedestrian plazas.

Perceived Walkability	The subjective perception of how easy and pleasant it is to walk in a specific urban environment.
Research Through Designing (RTD)	A research methodology in which the design process is not considered a final product but a means to expand the body of knowledge in landscape architecture and urban planning.
Resilient Cities	Cities that can quickly recover essential services and functions after disturbances or shocks.
Retrofitting	The process of upgrading or renovating existing buildings and infrastructure to make them more energy-efficient, environmentally friendly, or socially functional.
Smart City	An urban development approach using information and communication technologies to improve city efficiency and livability.
Smart Growth	A planning approach that supports development within existing urban areas, promotes mixed land uses, and pedestrian-friendly streets.
Snowball Sampling	A sampling technique where initial participants suggest or refer additional individuals who may be relevant to the study, creating a chain-like network of participants.
Social Cohesion	The sense of connectedness and community among residents in a specific area, often fostered by shared spaces and activities.
Spatial Integration	The process of harmoniously combining different elements within a given space or area to create a cohesive and functional whole.
Stepping Stones	Small habitat patches that act as intermediate connecting points within a fragmented landscape.
Stormwater Management	Techniques and strategies employed to manage the runoff from rain or melting snow in urban areas, including green infrastructure elements like rain gardens and bioswales.
Structural Connectivity	The physical connections between landscape elements, such as habitat patches and corridors.
Suburban Development	A form of urban development characterized by low density, automobile reliance, and land-use specialization.
Sustainability	Meeting present needs without compromising future generations' ability to meet their own needs in urban planning.
Sustainability Characteristics	The features and qualities of a system or environment that contribute to its overall sustainability and resilience.
Transit-Oriented Development (TOD)	A land-use and transportation strategy that promotes dense, mixed-use development centered on public transit stations.
Urban Biodiversity	The diversity of plant and animal species found in urban environments, including parks, green spaces, and other urban habitats.
Urban Design	The process of shaping the physical layout and form of cities to create functional, aesthetically pleasing, and sustainable urban spaces.
Urban Ecology	The scientific study of ecosystems and biodiversity in the context of urban environments.
Urban Ecosystem Services	The benefits that urban areas derive from natural ecosystems within or near the city.

Urban Ecosystems	Ecological systems and habitats found within urban areas, including parks, gardens, and urban forests.
Urban Forest Management Plan	A strategic plan designed to guide the management and preservation of urban trees and green spaces in a city.
Urban Growth Centres (UGC)	Specific areas targeted for intensified development within larger urban regions, aiming to redirect development from downtown areas to other designated centers.
Urban Heat Island Effect (UHIE)	The phenomenon where urban areas experience higher temperatures compared to surrounding rural areas due to human activities, buildings, and limited green spaces.
Urban Planning	The process of designing and shaping the physical layout and organization of cities and urban areas.
Urban Public Open Spaces (UPOSs)	Publicly accessible outdoor areas in urban environments, such as parks, squares, plazas, and green spaces.
Urban Runoff	Rainwater and melted snow that flows over impervious surfaces in urban areas, picking up pollutants and carrying them into stormwater systems.
Urban Sprawl	The uncontrolled and unplanned expansion of urban areas into surrounding rural and natural lands, leading to low-density development.
Urbanization	The process of increasing the population and development of urban areas, resulting in the expansion of cities and towns.
Walkability	The measure of how friendly and conducive an urban area is for pedestrian movement.
Xeriscaping	A landscaping approach that emphasizes using drought-resistant and water-efficient plants to reduce water consumption.

Appendix B

Markham Questionnaire

1. What are the most significant natural features within Markham Centre?

2. How can we define environmental dimensions of the center (soil type, green cover percentage, impervious cover percentage, local biodiversity, urban heat island effect, environmental pollution sources, carbon footprint, and vulnerability to climate change)?

3. How did the environment of the location look like in the past (before becoming an UGC)?

4. Have the natural features of the centre been modified over time?

5. Rogue River and Valley are deterministic features here. How are they modified over time? What departments have managed the modifications?

6. Please talk about the protected natural features. Why are they endangered, by what acts or documents are you protecting them? How is the preservation defined in your planning documents?

7. What kind of planning models have affected the centre over time?

8. What are the environmental issues confronting the centre at the moment (Stormwater Runoff, flooding, habitat loss, biodiversity, groundwater recharge, creek channelization, integration of different areas of the centre, assuring connections between the centre and surrounding areas)?

9. Do these issues directly affect local residents? Are these issues visually evident?

10. What solutions are made for these issues? What are the inspirations for these solutions (literature, other centres in other cities, consultants, public participation in decision-making)?

11. What are the policies, programs, measures, and facilities for Low Impact Development?

12. Is there any implementation example to create a pleasant pedestrian environment? What obstacles are you confronting? What is changing now?

13. What have been the original local social characteristics and environmental perspectives of residents? What has happened to them over time?

14. Please briefly talk about the Advisory Committee. How do you see the significance of the local environment for the residents and the City? Are there any environmental activist groups here? How are residents contributing to the planning of Markham Centre?

15. How do you define the relationship between the City and these groups? Are there any stories about collaboration between the City and these groups?

16. How have high-traffic highways such as Highway 7 and 407 affected the environment of the Centre?

17. What are the environmental benefits of transforming Highway 7 into an urban boulevard?

18. What are your solutions for making the Centre more walkable? Have you identified similar issues (noise, pedestrian traffic lights) and what do you think about reasonable solutions?

19. What are the most important local industries? How do they affect the natural features of the centre?

20. How is green infrastructure integrated with the other strategies of downtown? How much thinking have you given to creating biodiversity, stormwater practices, and making green spaces for adding ecological and social benefits?

21. How could you deal with parking? Do you entitle all developers to construct green features like bioswales, even in temporary parking areas?

22. What are the decisions promoting green infrastructure in the centre? (Function of green infrastructure in terms of Stormwater management, Biodiversity, Climate change mitigation, and adaptation)

23. Have you studied the experiences of other cities like Berlin or Seattle and their environmental programs?

24. What types of trees and vegetation are going to be planted in the Centre for biodiversity? Do you have regulations for planting local vegetation?

25. Apart from bioswales in parking lots, what other measures are widely implemented in the Centre?

26. What are the guiding principles for Performance Measures? Who is responsible for their implementation? Are they practiced only on private sites or in public spaces as well?

27. Has the City evaluated the current progress toward its goals? What areas have been successful, and which have been more challenging?

28. What are the guiding principles in the buffer zones between developments and the Valley? What is the story behind areas where the buffer zone does not exist?

29. Do you think it is possible to allow high LEED and LID standard proposals in environmentally protected regions to increase intensification opportunities without damaging nature?

Mississauga Questionnaire

1. What are the transportation infrastructure issues confronting the centre (Automotive transportation, creating a pedestrian environment, improving public transportation, integration of different areas, ensuring connections with the surrounding area)?

2. What solutions have been made for these issues? What are the inspirations for these solutions (literature, other centres, consultants, public participation)?

3. How did Mississauga look before becoming an Urban Growth Centre (UGC)? How were its communities, transit availability, important businesses, environmental features, and sense of place?

4. How have high-traffic highways like 403 shaped the City Centre?

5. How do these highways affect public transit? For example, how do they work with Transitway and GO Bus services but create obstacles for MiWay?

6. How are MiWay and Transitway services governed? How does this governance affect your work as a transit planner?

7. What are the most important local industries? How do they affect transportation planning?

8. How is the pedestrian environment in downtown? What are you doing to create a pleasant pedestrian environment? What obstacles have prevented this in the past, and why do you think it will work now?

9. How will parking be managed in the City Centre?

10. What other important plans are working alongside Downtown21?

11. What are other strategies of the City to transform the City Centre from a suburban to an urban form in terms of transportation?

12. What is the significance of highways like 401, 403, and QEW to the local economy?

13. What is the significance of proximity to Toronto for the local economy?

14. How were the multi-modal street designs and multi-level transit networks developed? Were other cities' programs studied?

15. How do truck transportation considerations affect these new street designs?

16. Go Transit and MiWay are working efficiently in Mississauga. How will the new multi-modal street designs contribute to improving transportation infrastructure for local, regional, and long-distance transit?

17. How does the new LRT system fit with the overall downtown strategies?

18. What are the programs for environmentally conscious urban planning and design?

19. Has the City evaluated the current progress toward its transportation goals since Downtown21 was implemented? What successes and challenges have there been?

20. What are the most significant natural features of Mississauga City Centre?

21. How did Mississauga look like in the past (before becoming an UGC)?

22. How have the natural features of the centre been modified over time?

23. How have local creeks been modified over time? Were there any significant floods in the past?

24. What are the environmental issues of the centre related to population density, water quality, and infiltration? Do these issues affect local residents, and are they visually evident?

25. How can we define the environmental dimensions of the centre (soil type, green cover percentage, impervious cover percentage, local biodiversity, urban heat island effect, environmental pollution sources, carbon footprint, and vulnerability to climate change)?

26. What is the significance of the local environment for the residents and the City? How much is it appreciated? What locations are preserved? Are there any environmental activist groups?

27. How have high-traffic highways such as 403 shaped the environment of the City Centre?

28. What are the current environmental issues confronting the centre (Stormwater Runoff, flooding, habitat loss, biodiversity, groundwater recharge, creek channelization, integration of different areas, ensuring connections with surrounding areas)?

29. What solutions have been made for these issues, and what are their inspirations?

30. What are the policies, programs, measures, and facilities for Low Impact Development?

31. What planning models have affected the centre over time?

32. What have been the original local social characteristics and environmental perspectives of residents? How have they changed over time?

33. Are there any local environmental activist groups, and what are their demands?

34. How is the pedestrian environment in downtown? What are you doing to create a pleasant pedestrian environment, and why hasn't this been done before?

35. How is green infrastructure integrated with other downtown strategies, such as creating biodiversity, stormwater practices, and green spaces?

36. How will parking be managed to support new transportation strategies like the LRT system?

37. Have there been decisions promoting green infrastructure in the centre?

38. How have multi-modal street designs been developed? Were other cities' programs studied?

39. How do truck transportation considerations affect these new street designs?

40. What are the programs for environmentally conscious urban planning and design?

41. What types of trees and vegetation will be planted in the centre for biodiversity, and how will ecological regulations evolve?

42. How is the continuity of buildings and green infrastructure incorporated into new street designs?

43. Has the City evaluated the progress of Downtown21 since its implementation? What areas have been successful, and which have been more challenging?