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Equitable Implementation of Green Infrastructure
An Analysis of the City of Vancouver
Mise en oeuvre équitable d'infrastructure verte
Une analyse de la ville de Vancouver

Nicole Jang and Andréanne Doyon

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Article abstract

As climate change continues to pose a threat to human health, cities have turned to nature-based solutions, such as green infrastructure (GI), to lessen the impacts of climate change felt by communities. However, many practitioners are not incorporating equity considerations in GI siting decisions; thus, leaving marginalized and racialized communities to disproportionately bear the impacts of urban environmental issues. In the City of Vancouver, British Columbia, Canada, the GI Branch is investigating ways in which they can apply an equity lens to their work. To aid in their endeavour, this study examines existing challenges to equitably implementing GI, as well as areas for improvement, through a literature review, document and planning tool analysis, and key informant interviews. Drawing from the findings, this paper develops a set of equity criteria, which centre three dimensions of social equity: distributional, recognitional, and procedural equity, to help practitioners operationalize equity in GI project evaluations.

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Equitable Implementation of Green Infrastructure

An Analysis of City of Vancouver

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Abstract

As climate change continues to pose a threat to human health, cities have turned to nature-based solutions, such as green infrastructure (GI), to lessen the impacts of climate change felt by communities. However, many practitioners are not incorporating equity considerations in GI siting decisions; thus, leaving marginalized and racialized communities to disproportionately bear the impacts of urban environmental issues. In the City of Vancouver, British Columbia, Canada, the GI Branch is investigating ways in which they can apply an equity lens to their work. To aid in their endeavour, this study examines existing challenges to equitably implementing GI, as well as areas for improvement, through a literature review, document and planning tool analysis, and key informant interviews. Drawing from the findings, this paper develops a set of equity criteria, which centre three dimensions of social equity: distributional, recognitional, and procedural equity, to help practitioners operationalize equity in GI project evaluations.

Résumé

Tandis que le changement climatique continue à menacer la santé humaine, les villes explorent des solutions basées sur la nature, telles que l'infrastructure verte (IV), afin d'atténuer les impacts du changement climatique ressentis par les communautés. Toutefois, de nombreux praticiens n'intègrent pas les considérations d'équité dans les décisions de mise en œuvre d'IV, laissant ainsi les communautés marginalisées et racialisées affectées disproportionnellement par des problèmes environnementaux urbains. Dans la ville de Vancouver, en Colombie-Britannique, la succursale IV étudie les moyens d'appliquer une optique d'équité à leur travail. Afin de l'aider dans cette démarche, cette étude examine les défis actuels de la mise en œuvre équitable d'IV, ainsi que les points à améliorer, par le biais d'une analyse documentaire, d'une analyse des documents et des outils d'aménagement, et d'entretiens avec des informateurs clés. À partir des résultats, cet article développe un ensemble de critères d'équité, qui se concentre sur trois dimensions de l'équité sociale (l'équité distributive, l'équité de reconnaissance et l'équité procédurale) afin d'aider les praticiens à opérationnaliser l'équité dans les évaluations de projets IV.

Keywords:

Green infrastructure, Equity, Planning, Vancouver

Mots-clés:

Infrastructure verte, Équité, Aménagement, Vancouver

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Introduction

Nature-based solutions, such as green infrastructure (GI), have seen a significant increase in uptake in cities globally as a means of adapting to climate change and providing an array of ecosystem services (ESS) to residents (Connop et al., 2016; Di Marino et al., 2019; Hansen & Pauleit, 2014; Kabisch et al., 2017; Kremer et al., 2016; Majekodunmi et al., 2020; Seddon et al., 2021). While many cities have implemented climate action measures, they continue to struggle with operationalizing climate equity (Chu & Cannon, 2021; Shi et al., 2016). The City of Vancouver, British Columbia, Canada, is one example. While the City has been recognized globally for its work towards environmental sustainability since the 1990s (City of Vancouver, 2022), due to their ambitious climate action targets and initiatives, equity has not been a focus of this work until recently. The GI Branch, which is responsible for the implementation of nature-based solutions across the City, is exploring ways to consider social equity in decision-making processes, as GI siting decisions have thus far been opportunistic, with funding being the main driver of GI placement (Conger et al., 2019; GI 2021, personal communication, 12 January).

The objectives of the paper are to: 1) conceptualize social equity in the context of GI; 2) help improve the operationalization of equity within the GI Branch in the City of Vancouver; and 3) develop equity criteria that can be used within existing planning tools to bring equity to the forefront of GI practice. The paper begins by reviewing the literature to identify current challenges and compare approaches to determine best practices for the equitable implementation of GI. Then, it examines how equity is being incorporated into the GI Branch's work through an analysis of City documents and planning tools and semi-structured interviews with City staff. Although the research is specific to the City of Vancouver, the proposed equity criteria can be applied to GI planning, decision-making, and implementation processes in cities worldwide.

Literature Review

Conceptualizing Social Equity in the Context of GI

Equity "...does not seem to be ever-present in the minds of GI-related personnel, as it deserves to be" (Jayakaran et al., 2020, p. 4). This is a matter of great concern, as the implications of neglecting equity in GI siting decisions can raise issues of environmental justice. The distribution of urban greenery tends to favour more white, affluent communities, leaving racialized and socioeconomically disadvantaged communities to bear the disproportionate impacts of urban environmental issues, such as the urban heat island (UHI) effect (Byrne et al., 2009; Dahmann et al., 2010; Dai, 2011; Landry & Chakraborty, 2009; Wolch et al., 2014). Conjointly, this also means that these communities are often left out of receiving the ecosystem services (ESS) provided by GI. ESS are the benefits that humans can acquire from ecosystem functions (Millennium Ecosystem Assessment, 2005). Such benefits include but are not limited to, the mitigation of flood risk through stormwater management (Ahern, 2007; Lennon et al., 2014; Liu & Jensen, 2018), a reduction in the urban heat island (UHI) effect (Bowler et al., 2010; Marando et al., 2019), a decrease in urban air pollution (Jayasooriya et al., 2017; Pugh et al., 2012), and improved human health and well-being (Alcock et al., 2014; Kardan et al., 2015; Tzoulas et al., 2007). While planners may have good intentions when sitting GI in an area, their decisions may have unintended consequences if equity is not considered (Jayakaran et al., 2020; Wolch et al., 2014). Therefore, although the predominant knowledge systems influencing GI implementation are engineering and ecological

(Matsler, 2019), planning and decision-making processes surrounding GI must also consider social factors, especially those of equity.

While equity is far from being at the forefront of GI siting considerations (Kronenberg et al., 2020), scholars and practitioners are demonstrating efforts to incorporate equity into their work. An example of this can be seen in Matsler et al. (2021) expansion of their original conceptualization of the "eco-techno spectrum," which places GI assets on a spectrum according to the proportion of biologicalcomponents to human-made technological components it possesses (Matsler, 2019). In the revised version of the model, an overarching social section, containing questions that examine the political, institutional, financial, and cultural aspects of implementation, is placed on top of the original GI classification spectrum to guide the placement of an asset (Matsler, 2021); thus, showing the importance of social considerations in GI planning.

While the integration of equity into GI work is still an ongoing challenge, there is an extensive amount of literature that has examined the provision of urban greenery or stormwater management solutions through an equity or justice lens (see Boone et al., 2009; Heckert & Rosan, 2016; Kabisch & Haase, 2014; Kronenberg et al., 2020; Landry & Chakraborty, 2009; La Rosa & Pappalardo, 2020; Ma, 2020; Nicholls, 2001; Sister et al., 2010; Wang & Palazzo, 2021; Wang et al., 2019; Xiao et al., 2017; Zafra-Calvo et al., 2017; Zhu et al., 2019). However, many of these articles (Boone et al., 2009; Landry & Chakraborty, 2009; La Rosa & Pappalardo, 2020; Ma, 2020; Sister et al., 2010; Wang et al., 2019) take Lucy (1981)'s equality approach to equity and assume that any deviation from equality is an inequity, without providing an adequate explanation as to why this specific approach should serve as the benchmark for equity (Heckert & Rosan, 2016). While used quite often, an equality as equity approach to GI planning does not adequately address the needs of equity-denied groups (ibid.). Therefore, an approach that correlates with Lucy (1981)'s needs-based approach to equity is more desirable in the context of GI planning, as it targets those who need infrastructure and services the most (Heckert & Rosan, 2016; Nicholls, 2001). An application of this can be seen in Heckert and Rosan's (2016) "GI Equity Index", where they make a case for equitable GI investments by identifying areas in Philadelphia, USA that would most benefit from the provision of GI. The difference between equality versus needs based is spreading GI across a city and targeting areas with higher levels of vulnerability or risk.

There is a tendency of GI scholars to focus on the distributional aspect of equity (see Boone et al., 2009; Heckert & Rosan, 2016; La Rosa & Pappalardo, 2020; Ma, 2020; Nicholls, 2001; Sister et al., 2010; Wang et al., 2019; Xiao et al., 2017; Zhu et al., 2019), leaving recognitional and participatory equity largely underrepresented in GI literature and practice. This can bring forth issues of environmental injustice, as well as disproportionate impacts to racialized and marginalized communities (Schlosberg, 2004, 2007; Walker, 2012). However, some studies exist that examine green spaces, urban forestry, environmental management, and stormwater management through all three dimensions of equity (see Kabisch & Haase, 2014; Kronenberg et al., 2020; Lecuyer et al., 2018; Nesbitt et al., 2018, 2019; Wang & Palazzo, 2021; Zafra-Calvo et al., 2017).

A Framework for Assessing Social Equity in the Context of GI

To assess the equitable implementation of GI, we draw on Meerow, et al. (2019)'s tripartite framework of social equity in urban resilience planning, see Table 1. The framework includes dimensions of

distributional, recognitional and participatory equity, which we believe are all necessary to achieve the equitable implementation of GI. In addition, the framework included GI within an understanding of urban resilience. The distributional dimension of equity in the framework considers how equitable, or inequitable, the distribution of resources, services, infrastructure, and economic opportunities are across a city (Meerow et al., 2019). Using Lucy (1981)'s needs-based approach to distributional equity as a reference point for the remainder of this paper, an equitable allocation of resources across a city would first accommodate for the welfare of those it is a necessity for (e.g., marginalized and racialized communities). Through their analysis of this dimension of equity, Meerow et al. (2019) review and code resilience plans and strategies for text that describes how inequitable the current distribution of resources, services, infrastructure, and economic opportunities are across the city in question, what the ideal, equitable distribution would look like, and any strategies to improve the current, presumably inequitable state of distribution. While their analysis draws from resilience plans and strategies, we believe that this framework can also be used to assess the equitable implementation of GI, as it focuses on equity.

The next dimension of equity they consider is recognitional equity, which refers to the recognition and respect of marginalized and racialized groups, the disproportionate impacts they face, and the historical and systemic decisions that have resulted in their disadvantage (Meerow et al., 2019). As argued by Fraser (1998, 2003), Schlosberg (2004, 2007), Walker (2012), and Young (1990), it is important to acknowledge the underlying structural inequalities that have led to various injustices felt by different groups, as traditional planning and decision-making processes have and continue to disproportionately impact these groups.

The third dimension of equity, procedural equity, which can be equated to Schlosberg (2004, 2007)'s participatory equity, examines the extent to which public participation and engagement are inclusive in planning and decision-making processes at all stages and to all groups (Meerow et al., 2019). In their analysis of this dimension, particular focus is given to the meaningful inclusion of marginalized groups and any initiatives that can help to strengthen their participation, as participatory processes typically favour more privileged voices and keep the most marginalized in the periphery (Anguelovski et al., 2016; Meerow et al., 2019). Furthermore, since Lucy

Table 1. Meerow et al. (2019)'s Tripartite Framework of Social Equity.

Dimension of Equity	Definition	Components
Distributional	The equitable distribution of goods, infrastructure, services, and opportunities across a city.	- Goods and infrastructure. - Services. - Opportunities. - Environmental amenities and disamenities.
Recognitional	The acknowledgement and respect of different equity-denied groups.	- Recognizing different groups' histories and needs. - Promoting respect.
Procedural	Inclusive and equitable participation in planning and decision-making processes.	- Participation in plan development. - Participation in governance. - Outreach to equity-denied groups.

(1981)'s needs-based approach to equity focuses on addressing the needs of those who need it the most, it is important that these groups are purposefully given a voice in engagement processes, because historical instances of institutional exclusion have and continue to discourage them from participating (Fraser, 1998; Schlosberg, 2004, 2007).

Methodology

The aim of this research is twofold, 1) to investigate how equity is being operationalized within the City of Vancouver's GI Branch, and 2) to develop equity criteria that can be used with existing planning tools, with the goal of bringing equity to the forefront of GI practice. Two methods were employed to collect data to inform this work: document analysis and semi-structured interviews. The findings from the data collection were then analyzed with the literature review to identify ways in which the GI Branch could strengthen equity considerations in the implementation of GI.

First, an analysis of the *Rain City Strategy* was performed. This strategy is the City of Vancouver's primary GI strategy because the City defines and works with the term as an approach to rainwater management "...that uses both engineered and ecosystem-based practices to protect, restore and mimic the natural water cycle" (Conger et al., 2019, p. 5). The document was examined for mentions of

Table 2. The City of Vancouver's GI Branch's Project Opportunities Evaluation Tool.

Criteria	Description	Priority Weighting
Timing and Urgency	Does the timeline of the project limit opportunities for the GI team to provide input and conduct pre-design work?	3
Sewershed and Receiving Waterbody Rating	Rating is based on targeted waterbodies for cleanup or sewersheds for reduced combined sewer overflow.	1
Infiltration Potential	Depends on the soil type, groundwater table, bedrock depth, and steepness of slopes.	2
Available Space for GI	Based on the density of the site and open space.	3
Available Drainage Area and High Pollutant Capture Opportunity	Does the project have an opportunity to capture runoff from a large impervious drainage area and/or high pollutant generating area?	1
Underserved Neighbourhood	Neighbourhoods with fewer trees and green space, low income, and not undergoing redevelopment any time in the near future.	1
Visible GI and Educational Opportunity	Will the GI practice be on the surface and visible to the public? Can it provide educational opportunities to schools?	1
Potential Loss of Parking Spaces	Do the likely GI options eliminate parking spaces?	1
Co-benefit Potential	Do the likely GI options meet other planning objectives and provide other co-benefits to the area?	1
Engaged Community	Is there a community desire for GI? Is there a need for GI introduction and education? Is there opposition to GI?	1
Funding	Is funding for the project available? How much?	3

equity, as well as links that had been established between equity and GI. It was then scanned for text describing each of the three dimensions of equity (distributional, recognitional, and procedural) from Meerow et al. (2019)'s framework. Next, the criteria and factors for two planning tools that are used for implementation in the GI Branch, the *Project Opportunities Evaluation Tool* and Geographic Information Systems (GIS) suitability analysis maps, were reviewed to examine the extent to which equity was integrated into GI planning and implementation processes.

The *Project Opportunities Evaluation Tool* assesses potential GI projects through a prioritization scoring system. The tool (see Table 2) has eleven criteria that are scored from 0 to 10, with 10 being in favour of doing the project. Each criterion is also assigned a priority weighting from 1 to 3, with 3 giving the factor more importance. Final weighted scores, which determine if projects should be pursued or not, are calculated by summing the criteria scores and multiplying them by their priority weight. As the tool was created in 2017, the GI Branch indicated that the tool needed to be updated, especially with regard to its equity-related criteria (GI 2021, personal communication, 8 March). The GIS suitability analysis maps are used in the GI planning process to map out various spatial factors that influence and can be influenced by the placement of GI, such as land use cover and the UHI effect (ibid.). The GI Branch requested input on current and additional layers that could be used within these analyses to further equitable GI work, as they indicated that they were in the early stages of integrating equity-related layers into their maps (ibid.). The analysis of the *Rain City Strategy* and review of planning tools provided a baseline understanding of the existing relations surrounding equity and GI within the City of Vancouver.

Second, semi-structured interviews were conducted with eight individuals from three key groups within the City of Vancouver: 1) the GI Branch, 2) Engineering Services, and 3) others who actively worked with equity (Leaders in Equity), as well as personal communication with three other members of the GI Branch, see Table 3. The formulation of the interview questions was guided by information obtained from the document and

Table 3. City of Vancouver Key Informant Interviewee Categories, Departments, and Branches.

Category	Department and Branch
GI Branch	Engineering Services – GI Implementation
GI Branch	Engineering Services – GI Implementation
GI Branch	Engineering Services – GI Implementation
Engineering	Engineering Services – Clean Waters Planning
Engineering	Engineering Services – Sewer and Drainage Design
Engineering	Engineering Services – Sewer and Drainage Design
Leaders in Equity	Engineering Services – GI Implementation (Equity Lead)
Leaders in Equity	Arts, Culture, and Community Services – Social Policy and Projects
Leaders in Equity	Planning, Urban Design, and Sustainability – Sustainability Group

planning tool analysis on the application of social equity in GI practice. Individuals from the GI Branch were interviewed to gain further insight on GI planning and decision-making processes, as well as the integration of equity into everyday operations. Perceptions on GI and equity were then gathered from individuals in the Engineering Services department, as the GI Branch lies within this department, and contacts within the GI Branch indicated that they would be the group with the most leverage when it comes to investing in and implementing GI projects (GI 2021, personal communication, 9 February). Finally, internal Leaders in Equity were interviewed to understand how equity was viewed and being used in the City of Vancouver. Interviews were transcribed, and responses were grouped based on discussions around definitions of equity, how staff identified equity-denied groups, and how staff prioritized and incorporated equity into their work. Common themes amongst respondents were then identified and summarized to inform the research. See Appendix A for interview questions.

City of Vancouver GI Equity Challenges

Weak Inclusion of Equity in the Primary GI Strategy

The *Rain City Strategy* and City of Vancouver staff primarily view and use GI for the purpose of rainwater management. However, efforts to recognize the importance of GI beyond its use for rainwater management are evident in the *Rain City Strategy*. "GRI [green rainwater infrastructure]

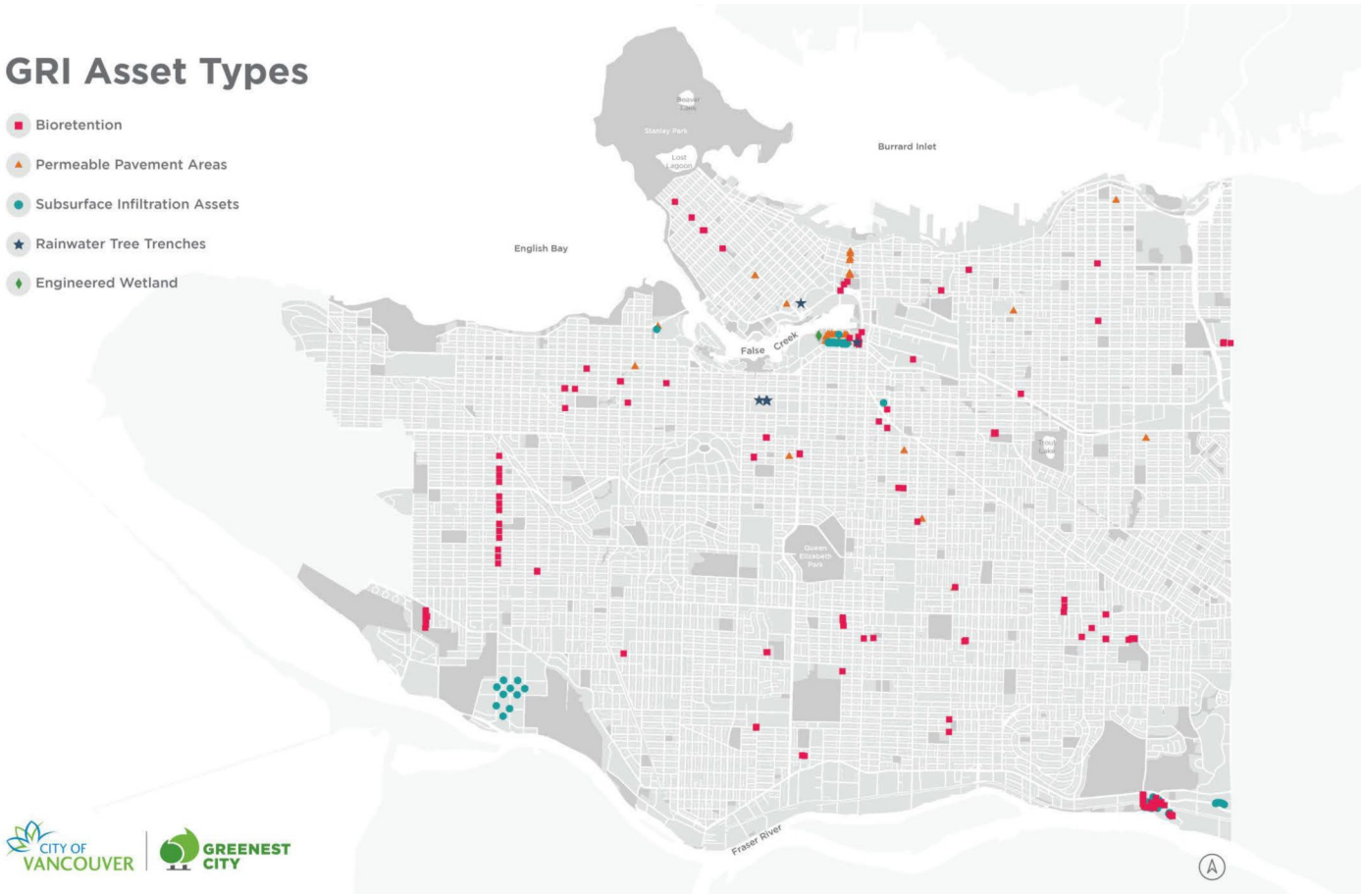

Figure 1. City of Vancouver Green Infrastructure Assets (Conger, et al., 2019, p. 50).

implementation sits in a distinct position as it can be found at the intersection of a variety of equity-related topics. Concepts such as neighbourhood resiliency, public health, environmental justice, public participation, capacity-building and place-making can all be found within the sphere of influence of a GI project" (Conger et al., 2019). This quote encapsulates the position of GI at multiple intersections, as well as the GI Branch's efforts to incorporate equity. However, when viewing the document through the lens of Meerow et al. (2019)'s tripartite framework of social equity, it was revealed that the *Rain City Strategy* only touched on aspects of distributional and procedural equity and lacked recognitional equity.

In terms of distributional equity, the document successfully acknowledged that opportunistic implementation was a challenge to the distribution of GI across the city (see Figure 1 for a map of existing GI assets and Figure 2 for a map of the urban heat island effect across the City), as well as the need for a shift in approaches if the City is to meet its policy goals and objectives concerning water (Conger et al., 2019). It also provided a general list of inequities that could arise from rainwater management practices, as well as a few spatial indicators that could be considered when prioritizing the placement of GI. However, the *Rain City Strategy* failed to describe: 1) the current, inequitable distribution of resources and infrastructure in a local context, 2) how an equitable distribution would look across the city, and 3) any

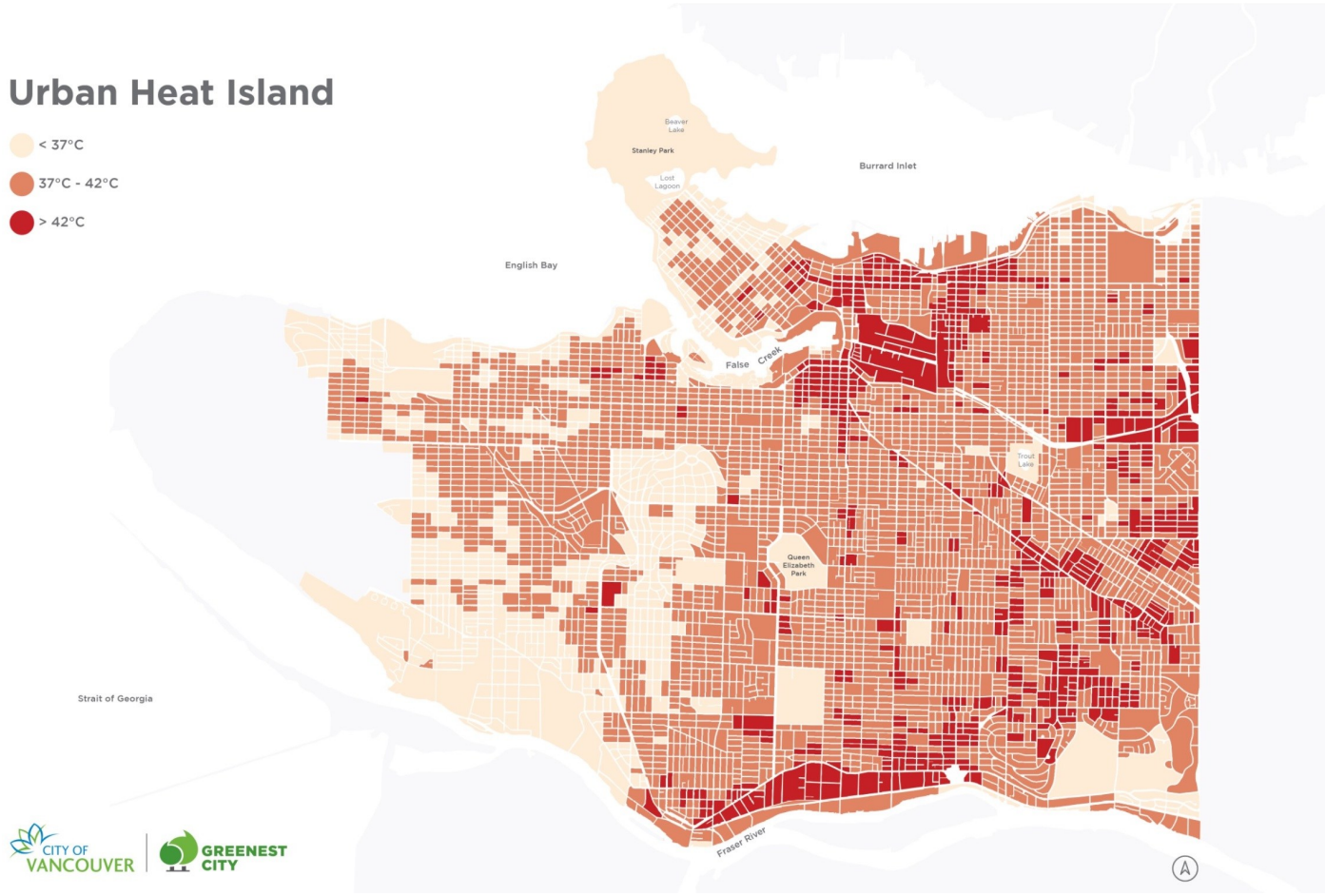

Figure 2. Urban Heat Island Effect in Vancouver (Conger, et al., 2019, p. 60).

Figure 3. Range of Individuals from the Community, Academia, and Industry Contributed Input on the Creation of the *Rain City Strategy* (City of Vancouver, 2018).

strategies to address the inequities (Meerow et al., 2019). Moreover, while the document mentioned that GI had the capacity to provide "economic opportunity and green jobs for local communities" (Conger et al., 2019, p. 79), it did not mention or outline any current situations regarding inequitable access to economic opportunities in Vancouver, nor how an equitable situation would look (Meerow et al., 2019).

Text relating to recognitional equity was the *Rain City Strategy*'s weakest area. Recognitional equity calls for the acknowledgement of equity-denied groups, as well as the systemic oppression they face due to historical and traditional planning and policy practices (Lee & Huang, 2020; Mah et al., 2020; Meerow et al., 2019). The *Rain City Strategy* does not explicitly mention who the equity-denied groups in Vancouver are, nor the historical contexts that have led to their marginalization. Instead, a definition of vulnerable communities, sourced from the USA Water Alliance, was provided. While the definition acknowledged various socioeconomic factors that could indicate an equity-denied community, as well as the fact that such communities are disproportionately impacted, it failed to identify specific communities within Vancouver itself. It is important to regularly name and identify racialized and marginalized groups in a local context, as planners and decision-makers need to understand who these individuals are and what impacts they face (Lee & Huang, 2020; Mah et al., 2020).

Procedural equity was the *Rain City Strategy*'s strongest dimension of social equity. An appendix outlining the extensive public engagement process that went into the development of the document was included. Staff working on the strategy held numerous "...open houses, workshops, surveys, educational events, and expert panel meetings" (Conger et al., 2019, Appendix E, p. 2). Through this, a range of individuals from the community, academia, and industry gave input on the creation of the *Rain City Strategy* (ibid.) (see Figure 3). Additionally, in terms of participation, the *Rain City Strategy* specified that building GI equitably would "...allow [for] designs of GI to be meaningfully shaped by the concerns, needs and

desires of the community to help enhance community involvement and reduce displacement" (Conger et al., 2019, p. 80). However, it was unclear the extent to which equity-denied groups were included during the development period and would be included in other stages of work, such as the design stage. It is crucial to meaningfully engage with these groups during participatory processes and throughout the working process, as they are often underrepresented (City of Vancouver, 2020; Mah et al., 2020; Meerow et al., 2019).

Lack of Equity Factors in Planning Tools

The City of Vancouver has two internal planning tools for GI implementation: the *Project Opportunities Evaluation Tool* and GIS suitability analysis maps. As previously mentioned, the *Project Opportunities Evaluation Tool* assesses potential GI projects through a prioritization scoring system. The scoring for each criterion is highly subjective, as users of the tool rely on experience and personal judgement during the scoring process (GI 2021, personal communication, 8 March). Currently, of the eleven factors considered, only four address social topics; those being 1) underserved neighbourhoods, 2) visible GI and educational opportunity, 3) co-benefit potential, and 4) engaged community. However, they do not adequately address issues of equity nor centre equity considerations in practice.

The 'underserved neighbourhoods' factor has the potential to demonstrate recognitional equity by recognizing the intersectionality of identities in a neighbourhood and using that information to determine project placements. Yet, it only uses three variables (lack of trees and green space, low income, and no redevelopment in the near future) to determine if a neighbourhood is underserved or not. The 'visible GI and educational opportunity' and 'engaged community' factors have the potential to demonstrate procedural equity in their evaluation by engaging with equity-denied groups and nearby schools. However, they both take on hands-off approaches to engagement. The 'visible GI and educational opportunity' factor assumes that the visibility of GI in an area is directly correlated to the number of people who will think about rainwater management in the city (GI 2021, personal communication, 8 March). However, remains an assumption. The 'engaged community' factor considers whether the community has already been engaged with regarding the project (GI 2021, personal communication, 8 March), and does not consider new engagement practices. The 'co-benefit potential' factor also has the potential to integrate equity, by evaluating their potential to equitably distribute ecosystem services to communities that need them the most. However, the factor only looks as if the project has synergies with planning objectives from other departments (GI 2021, personal communication, 8 March).

GIS suitability analysis maps are also used in the GI planning process, to map out various spatial factors that influence and can be influenced by the placement of GI, such as land use and the UHI effect (GI 2021, personal communication, 8 March; Conger et al., 2019). However, the integration of equity-related layers is still in its early stages (GI 2021, personal communication, 8 March). The GI Branch has recently introduced a 'disproportionately impacted communities' layer into their planning and decision-making processes. The layer contains variables such as visible minorities, Indigenous Peoples, seniors, single-parent families, individuals experiencing rent burden, households with low income, and individuals who speak limited English. While the layer demonstrates the GI Branch's progress with operationalizing equity, the maps require adjustments.

Issues Surrounding Equity Considerations in Practice

Issues surrounding considerations of equity in practice have recently been a substantial challenge for not only the GI Branch but the City of Vancouver as a whole (GI 2021, personal communication, 9 February). Many have acknowledged that integrating matters of equity into practice is still in the early stages and that it is necessary to learn more in order to move forward with this work (ibid.). Interviewees were asked about their definitions of equity to gauge their level of understanding of the topic. While no two definitions were the same, the majority of responses embraced Lucy (1981)'s needs-based approach to distributional equity by indicating that the distribution of services and resources across the city should be commensurate with need. This was to be expected, as much of the work that City staff does revolves around the distribution of services. Recognitional equity appeared several times in definitions from respondents, while procedural equity only explicitly appeared once. It was evident through conversations with staff that they were learning about equity through colleagues who were championing efforts but had not yet grasped a full understanding of the concept.

When asked how staff would identify disproportionately impacted areas in the city, with the exception of one interviewee from Engineering who had previous experience working with equity, the GI and Engineering groups generally fixated their responses on spatial and environmental factors, such as tree canopy cover, access to green space, and the UHI effect. Interviewees indicated that their GIS spatial analysis maps played a key role in helping to identify these areas in the city and prioritize investments for city-funded projects. While the GI and Engineering interviewees pointed to variables that lay more within their realm, the Leaders in Equity, who had both natural and social science backgrounds, pointed to more socioeconomic variables in their responses, such as income status, race, gender, seniors, and single-parent families.

As practicing equity requires individuals to recognize, engage with, and distribute services accordingly to equity-denied groups in the city, interviewees were asked about the extent to which they prioritized conversations about equity and incorporated it into their work. An individual from within the GI Branch observed that the planning team was generally more proactive at having conversations around equity, whereas the design team was prone to treating equity as an 'add-on' in the opportunistic advancement of GI (Leaders in Equity Interview 2). An individual from the design team confirmed this observation through their explanation of equity as a leverage point for GI implementation. They described the process as, "We opportunistically take advantage of any opportunity for GI, but we use disenfranchised areas and the equity lens as a compelling argument for them. When I say that, it sounds bad – like we're not taking into account equity. But I think on the flip side, we're not discriminating against any areas. We're just doing everything that we can everywhere" (GI Branch Interview 2). However, this individual also noted that this was changing, as individuals within the GI Branch were increasingly embracing equity in their work and recognizing its role in the workplace.

Operationalizing Equitable Green Infrastructure Implementation in the City of Vancouver

Project Opportunities Evaluation Tool

As previously mentioned, only four factors in the *Project Opportunities Evaluation Tool* address social topics: 1) underserved neighbourhoods, 2) visible GI and educational opportunity, 3) co-benefit potential, and 4) engaged community. However, these factors do not adequately consider equity in

practice. We propose the current factors be amended, and additional factors be added to the tool to bring equity considerations to the forefront. Table 4 contains the proposed changes. The new and revised criteria are organized using the three dimensions of social equity from Meerow et al. (2019)'s framework. The criteria were developed from findings in the literature review, document analysis, and interviews. It is worth noting that we specifically did not assess or develop new scoring or priority weights for the *Project Opportunities Evaluation Tool*, as it was understood to be highly subjective (GI 2021, personal communication, 8 March). While all the equity-related criteria should ideally have higher weights, we would emphasize increasing the weights of the 'benefit and burden distribution', 'disproportionately impacted communities', and 'engaged community' factors, as these factors capture significant aspects of distributional, recognitional, and procedural equity, respectively.

Distributional Equity Criteria

The 'co-benefit potential' factor currently assesses if cross-departmental planning objectives are achieved (GI 2021, personal communication, 8 March). For example, greenway projects are often given full points as they have synergies with active transportation, which contribute to the City of Vancouver's *Climate Emergency Action Plan* target of having active modes of transport make up two-thirds of all trips travelled by 2030 (City of Vancouver, 2020; GI 2021, personal communication, 8 March). While planning objectives are a satisfactory way to measure the potential of co-benefits, expanding this factor to include a question related to ecosystem services, to highlight the full range of co-benefits being provided to communities, would lead to more equitable outcomes not captured in existing plans or projects.

The 'benefit and burden distribution' factor evaluates infrastructure allocation from an equity perspective. It is important to ask "Who benefits from this project?" and "Who is left out of the benefits?" (Leaders in Equity Interview 3) to ensure that the benefits of a project are equitably distributed. In addition, assessing the distribution of burdens requires the consideration of potential unintended consequences of new projects. Since equity-denied groups already face several injustices, it is crucial that planners and decision-makers do not place further burden on such groups with a new project.

An 'economic opportunities' factor was created to determine if the distribution of economic opportunities was equitable. The factor considers what employment and training opportunities are available for equity-denied populations in new GI projects. The City of Oakland and New York City both have initiatives that target and measure the provision of green jobs for equity-denied populations. In Oakland, they provide employment opportunities for Black, Indigenous, and people of colour (BIPOC) youth, and in New York, they look to minority and women of colour-owned businesses during procurement processes (City of Oakland, 2020; Engineering Interview 1). This factor could help influence changes in procurement strategies to include equity criteria.

Recognitional Equity Criteria

The *Project Opportunities Evaluation Tool* currently uses three variables to denote an 'underserved neighbourhood': low income, lack of trees and green space, and no planned redevelopment in the near future. These variables were chosen because they were the easiest indicators to measure and identify (GI 2021, personal communication, 8 March). However, an 'underserved neighbourhood' cannot be reduced to three variables. It is crucial that planners and decision-makers recognize the intersectionality of identities and the disproportionate impacts felt by marginalized individuals (Fraser, 1998, 2003; Meerow et al., 2019; Schlosberg, 2004,

Table 4. New and Amended Equity-Related Criteria for the Project Opportunities Evaluation Tool.

Criteria		Description
Distributional Equity	Co-benefit Potential	Do the likely GI options provide a range of ESS to local communities? (e.g., provisioning, regulating, cultural, and supporting services) Do they help to meet other planning objectives?
	Benefit and Burden Distribution	Are the benefits being equitably distributed to those who need them the most? (i.e., who benefits from this project and who is left out of the benefits?) Does the project have potential unintended consequences that may place a further burden on equity-denied groups in the community?
	Economic Opportunities	Have employment or training opportunities been reserved for or provided to equity-denied individuals in the proposed project? (e.g., BIPOC, low-income individuals in the community, local women-owned businesses)
Recognitional Equity	Disproportionately Impacted Communities	Is this project situated in a disproportionately impacted area of the city? (Refer to GIS suitability analysis maps) Does this area have multiple intersections of marginalization? (i.e., are there several sociodemographic and built environmental factors that contribute to inequities in this area?)
	Historical Context	Has this area been historically underserved in terms of investments? (i.e., is this an area that needs funding due to inequitable past decisions or is it already heavily funded?)
Procedural Equity	Engaged Community	Is there a community desire for GI? Is there a need for GI introduction and education? Have equity-denied groups in the community been contacted and meaningfully engaged with? Will they be invited to participate? Are individuals in the community involved in the planning, design, construction, operation, and maintenance stages of the project if they desire to be?
	Educational Opportunities	Will the GI practice be visible to the public? Is there an opportunity for signage? Can it provide educational opportunities to schools or academic institutions in the area?
	Indigenous Perspectives	Are Indigenous voices, knowledge, or culture being integrated into the project? (e.g., through art or planting methods)

2007; Walker, 2012; Young, 1990). A 'disproportionately impacted communities' factor is better suited to evaluate these impacts. This factor aligns with the 'disproportionately impacted communities' GIS layer used by the GI Branch's planning team and includes far more criteria that are indicative of equity-denied areas, such as racialized groups, economically disadvantaged groups, and different age groups. It also determines the extent to which the area that the project is situated in is disproportionately impacted, to gauge the amount of need for GI.

The 'historical context' factor evaluates past investment decisions and determines whether current investments are being equitably placed within the city. An essential component of recognitional equity is acknowledging the historical and systemically racist decisions and decision-making processes that have and continue to cause equity-denied groups to experience various injustices (Fraser, 1998, 2003; Lee & Huang, 2020; Mah et al., 2020; Meerow et al., 2019; Schlosberg, 2004; Walker, 2012; Young, 1990). The factor considers whether investments are being equitably distributed, and if not, where investments should be guided to be more equitable and beneficial to equity-denied groups.

Procedural Equity Criteria

The 'engaged community' factor currently considers whether projects have gone through community engagement (GI 2021, personal communication, 8 March). To ensure the operationalization of procedural equity, the factor was expanded to encourage more meaningful engagement with equity-denied groups. Questions were added to inquire whether outreach has been or will be conducted at the beginning of a project and whether engagement has been maintained throughout the multiple stages of a project. The hope is that this factor can stimulate discussion on different ways to engage with existing and new residents, as well as track if existing community members are moving out due to green gentrification outcomes (Gould & Lewis, 2012).

The visibility of GI is a major determinant in the 'educational opportunities' factor. The idea is that the more visible GI is, the more people will think about rainwater and how it is managed in the city (GI 2021, personal communication, 8 March). However, this has not been confirmed. We shift the factor to focus more on educational opportunities that can arise from GI implementation and the different ways they can be manifested. This can include signage near GI projects, which has been shown to help address a lack of public education and acceptance (Brown & Farrelly, 2009; Chaffin et al., 2016; Dhakal & Chevalier, 2017; Jayakaran et al., 2020; Keeley et al., 2013; Winz et al., 2014; Zuniga-Teran et al., 2020; Leaders in Equity Interview 2). The 'educational opportunities' factor also includes a question regarding the provision of educational opportunities to schools and academic institutions, as this is another way to help the public understand the water cycle and stormwater management (Greater London Authority, 2020; State of Green, 2021).

The 'Indigenous perspectives' factor intends to distinguish Indigenous Peoples from other equity-denied groups because their lived experiences and traditional ecological knowledge are distinctly unique from those who have settled in Canada (Mah et al., 2020). This factor considers three different ways Indigenous perspectives can be included in GI projects. The first, Indigenous voices, asks if Indigenous Peoples' voices are being heard and centred during participation, planning, decision-making, and implementation processes. This is vital to procedural equity, as equity in this context means the inclusion of all groups in all processes (Meerow et al., 2019). Secondly, as the diversification of knowledge systems (Yumagulova & Vertinsky, 2019) is crucial to advancing both GI and equity in

planning, it is important that Indigenous knowledge systems are also included. Third, it is important to identify ways in which Indigenous cultures can be incorporated into GI projects, as it may also provide an opportunity to build relationships and encourage participation.

GIS Suitability Analysis Maps

As previously indicated, the City of Vancouver's GI Branch uses GIS suitability analysis maps in the planning process to assess spatial factors in the placement of GI. However, the maps require adjustments regarding their equity-related layers. In particular, the maps need to include disaggregated data and more GI-specific analyses. Additionally, the GIS maps need to be used in conjunction with other decision-making tools and processes, such as the *Project Opportunities Evaluation Tool*.

The 'disproportionately impacted communities' layer currently being used by the GI Branch was built by the Streets and Transportation team at the City of Vancouver to help prioritize equitable investments in transportation across the city. This means that the layer was not created through a GI lens but through a transportation lens. The intention behind utilizing the same layer for both teams was to align the two, as they work closely with each other on a regular basis. While the layer acts as a foundation for the GI Branch, a GI-specific analysis is also needed. Such an analysis may highlight different groups or needs that have been missed and will likely help discover additional layers that can be used in future analyses, such as socio-economic or environmental layers.

While the 'disproportionately impacted communities' layer demonstrates the GI Branch's eagerness to incorporate equity into practice, it is important to consider the implications of using aggregated data. As highlighted by Chen et al. (2019) in their equity analysis of the distribution of bike-sharing systems, "[t]he use of aggregated data might hinder our understanding of the equity impacts since individual disparities are absorbed after aggregation" (p. 530). By combining racialized groups with lower income groups, different age groups, and individuals with varying education levels, amongst others, the GI Branch is presumably masking a vast number of patterns and relations between the variables. This may have detrimental effects on equity-denied groups and individuals, as many experience compounded impacts due to the intersectionality of their identities (Meerow, et al., 2019; Schlosberg, 2007). This reiterates the importance of recognitional equity and consistently identifying and naming the equity-denied groups, as equity-denied groups have and continue to face injustices due to their neglect in planning and decision-making processes (Fraser, 1998; 2003; Walker, 2012; Schlosberg, 2004; 2007; Young, 1990).

Disaggregating the 'disproportionately impacted communities' layer will equalize the level of importance each variable is given. The GI Branch currently allocates individual layers for environmental factors, but not equity ones. This is problematic for equitable planning and decision-making because socio-demographic factors are essential to identifying disproportionately impacted areas of the city, as well as distributing services and infrastructure accordingly. Instead, a composite map should be created, where each socio-demographic and environmental factor are assigned their own layer, to equally distribute the influence that each factor has on planning and decision-making processes. This follows Heckert and Rosan (2016)'s "GI Equity Index", where they combine both socioeconomic and environmental factors in a GIS map and use it to identify "equity voids", or communities that would benefit from the ecosystem services provided by GI. Additionally, stakeholder or

priority weights and analyzing the trade-offs between variables could be incorporated, as executed in iterations of GIS-based GI analysis models by Heckert and Rosan (2018) and Meerow et al. (2019, 2020).

A list of possible variables was compiled and is presented in the table below (Table 5). Many of the sociodemographic variables included in the list were sourced from the Hazards and Vulnerability Research Institute (2014)'s Social Vulnerability Index (SoVI) and Statistics Canada (2019)'s Canadian Index of Multiple Deprivation (CIMD). These indices consist of numerous sociodemographic variables that are

Table 5. List of Possible Variables for the GIS Suitability Analysis Maps.

Category	Variables
Sociodemographic	• Black people, Asian people and/or other people of colour (separate variables for each race) (Hazards & Vulnerability Research Institute, 2014; Vancouver Board of Parks & Recreation, 2019). • Adults without a high school education (Hazards & Vulnerability Research Institute, 2014; Heckert & Rosan, 2016; Statistics Canada, 2019). • Female and/or non-binary people (separate variables for each gender identity) (Hazards & Vulnerability Research Institute, 2014; Statistics Canada, 2019). • People living alone (Statistics Canada, 2019). • People under age 5 or 6 (Heckert & Rosan, 2016; Hazards & Vulnerability Research Institute, 2014; Statistics Canada, 2019; Vancouver Board of Parks & Recreation, 2019; Zhu et al., 2019). • Recent immigrants (Statistics Canada, 2019). • Owner to renter ratio (Heckert & Rosan, 2016; Hazards & Vulnerability Research Institute, 2014; Statistics Canada, 2019). • People that have moved within the past 5 years (Statistics Canada, 2019). • People receiving government transfer payments (Hazards & Vulnerability Research Institute, 2014; Statistics Canada, 2019). • Dependency ratio (youth (0-14) and seniors (65+) divided by adults (15-64)) (Statistics Canada, 2019). • Unemployment rate (Hazards & Vulnerability Research Institute, 2014; Statistics Canada, 2019). • Foreign-born individuals (Statistics Canada, 2019).
Built Environment	• Impervious surfaces (Dagenais et al., 2016; Heckert & Rosan, 2016; Zhu et al., 2019). • Particulate matter levels (Heckert & Rosan, 2016; Kremer et al., 2016; Meerow & Newell, 2017). • Combined sewer overflows and runoff (Meerow & Newell, 2017) • Proximity to traffic (Heckert & Rosan, 2016). • Ozone levels (Heckert & Rosan, 2016). • Connectedness of habitats (Meerow & Newell, 2017).
Accessibility and Health	• Access to green spaces (e.g., parks) (Madureira & Andresen, 2014; Meerow & Newell, 2017; Vancouver Board of Parks & Recreation, 2019; Zhu et al., 2019). • Disabled people (Vancouver Board of Parks & Recreation, 2019). • Wellness score (Vancouver Board of Parks & Recreation, 2019). • Indigenous health indicators (community-based and informed by a relevant Indigenous perspective) (Vancouver Board of Parks & Recreation, 2019).
Investment	• Areas of urban growth (Vancouver Board of Parks & Recreation, 2019). • Locations of past capital investments (Vancouver Board of Parks & Recreation, 2019).

indicative of existing vulnerabilities that would likely further exacerbate impacts from environmental hazards (Hazards and Vulnerability Research Institute, 2014; Statistics Canada, 2019). In terms of built environment variables, many were sourced from GIS models that evaluated the equity or multifunctional use of GI placements. The remaining variables were sourced from the Vancouver Board of Parks and Recreation, as they identified a set of variables for their own future equity analyses.

We recognize the list is quite extensive, and that not all variables may be implementable short term. We argue that integrating disaggregated racialized demographic data is given greater priority, as differentiating between populations can help increase awareness of their distinct lived experiences among planners and decision-makers; thus, hopefully resulting in more equitable outcomes for such individuals. We also want to emphasize integrating layers with impervious surfaces, combined sewer overflows, and sea level rise, as these can help to identify areas that are likely to be disproportionately impacted by the UHI effect, water pollution, and flooding. It would also be beneficial to create layers that illustrate past, current, and future investments to reflect on distribution decisions. A layer containing locations of past capital investments not only aligns with the proposed 'historical context' factor in the *Project Opportunities Evaluation Tool* but would also help identify such areas with ease and determine whether those areas require attention.

Discussion and Conclusion

As noted previously, there is a tendency of GI scholars to focus on the distributional aspect of equity; recognitional and participatory equity are largely underrepresented in GI literature and practice (see Boone et al., 2009; Heckert & Rosan, 2016; La Rosa & Pappalardo, 2020; Ma, 2020; Nicholls, 2001; Sister et al., 2010; Wang et al., 2019; Xiao et al., 2017; Zhu et al., 2019). For the City of Vancouver's GI Branch, procedural equity was the strongest dimension of social equity, followed by distributional, then recognitional. This was mostly due to the GI Branch's emphasis on public engagement in the development of the *Rain City Strategy*, as well as ongoing engagement with communities for new GI projects. Although there is relatively good awareness of distributional impacts, most actions do not support the equitable distribution of GI. Furthermore, the GI Branch, through the *Rain City Strategy*, *Project Opportunities Evaluation Tool*, and GIS suitability analysis maps, do not name and identify equity-denied groups, nor derive definitions or factors from the local context.

Operationalizing equity "entails decisions about who is most socio-economically and physically vulnerable to threats, how to allocate limited resources and tradeoffs related to the policies in the plans" (Meerow et al., 2019, p. 805). To do this, we need to engage with multiple dimensions of equity (distributional, recognitional, and procedural). Meerow et al.'s (2019) framework was used to assess the City of Vancouver's equitable implementation of GI, which produced the findings above. The assessment was also used to inform the development of equity factors for the GI Branch's *Project Opportunities Evaluation Tool*. The distributional equity factors assess synergies and co-benefits with other initiatives and ecosystem services; geographic benefit and burden, including the consideration of unintended consequences; and economic opportunities to distribute resources more equitably. The recognitional equity factors evaluate disproportionately impacted communities by emphasizing plurality within and across communities; and historical context, which considers previous investments from the perspective of exclusion or benefit to equity-denied groups. The procedural equity factors assess meaningful and ongoing

engagement; educational opportunities, including variety and partnerships; and Indigenous engagement, which seeks to elevate Indigenous voices, knowledge, and culture.

GI implementation goes beyond technical and biological considerations. Political, institutional, financial, and cultural aspects need to be incorporated into GI decision-making processes (Matsler et al., 2021). Neglecting these aspects can perpetuate and exacerbate existing inequities or create new ones (Gould & Lewis, 2012; Jayakaran et al., 2020; Wolch et al., 2014). Incorporating social considerations into GI decision-making processes can help to mitigate inequities, as well as emphasize the importance of place in planning and implementation. Technical and biological considerations tend to focus on location (space), while social considerations emphasize history and people (place). These considerations will differ across and within cities. Although the equity criteria from this research were developed for the City of Vancouver's GI Branch, the questions and variables can be used by other researchers and practitioners to incorporate social considerations and improve the operationalization of equity into GI planning and decision-making processes. As cities continue to struggle to incorporate equity into climate action, examining the City of Vancouver's attempts to practice equitable implementation of GI offers opportunities for learning and self-reflection for other cities.

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Appendix A. Interview Questions.

Questions for GI Branch

General

1. Can you state which department and branch you are from?
2. How long have you been working with this team? How long have you been working with the City of Vancouver?

GI

3. How does the planning and decision-making process for GI work? Can you briefly take me through the process?
4. What are the relationships like when it comes to interdepartmental collaboration on GI projects? From your experience, what works well and what could be better?
5. What do you think are the largest barriers to GI implementation?

Resilience

6. How would you define resilience?
7. To what extent do you incorporate resilience into your everyday work? For example, are there resilience dimensions or metrics that you consider in your planning and decision-making processes?

Equity

8. How would you define and measure equity?
9. How would you identify or classify a disadvantaged area of the city?
10. To what extent do you incorporate equity into your everyday work? For example, are there equity dimensions or metrics that you consider in your planning and decision-making processes? Do you intentionally prioritize equity and have discussions about it on a regular basis?
11. Do you see GI, resilience, and equity as being related to each other?
    a. If yes, are there any opportunities you can identify in your work that can connect the three concepts? Or is this something you are striving for in your work?
    b. If no, why?
12. What is one thing you would want to learn about, or one question you would need answered, in order to successfully incorporate equity into your everyday work?

Questions for Individuals in Engineering

General

1. Can you state which department and branch you are from?
2. How long have you been working with this team? How long have you been working with the City of Vancouver?

GI

3. How do you define GI?
4. How do you decide on what rainwater management approach is suitable for a project?
5. Have you ever considered GI as a solution or something that you can use to help you to meet your planning objectives? Or to achieve co-benefits in your work?

a. If yes, how, and what areas of your plans or projects align with GI?

b. If not, why? Are there communication or knowledge barriers hindering this?

Resilience

6. How would you define resilience?
7. To what extent do you incorporate resilience into your everyday work? For example, are there resilience dimensions or metrics that you consider in your planning and decision-making processes?
    a. If not, what related term do you use as a framework or foundation to your work?

Equity

8. How would you define and measure equity?
9. How would you identify or classify a disadvantaged area of the city?
10. To what extent do you incorporate equity into your everyday work? For example, are there equity dimensions or metrics that you consider in your planning and decision-making processes? Do you intentionally prioritize equity and have discussions about it on a regular basis?

11. Do you see GI, resilience, and equity as being related to each other?
    a. If yes, are there any opportunities you can identify in your work that can connect the three concepts? Or is this something you are striving for in your work?
    b. If no, why?
12. What is one thing you would want to learn about, or one question you would need answered, in order to successfully incorporate equity into your everyday work?

Questions for the Leaders in Equity

General

1. Can you state which department and branch you are from?
2. How long have you been working with this team? How long have you been working with the City of Vancouver?

Equity

3. How would you define and measure equity?
4. How would you identify or classify a disadvantaged area of the city?
5. To what extent do you incorporate equity into your everyday work? For example, are there equity dimensions or metrics that you consider in your planning and decision-making processes? Do you intentionally prioritize equity and have discussions about it on a regular basis?
6. Can you take me through the development and implementation process of a specific project/ program/policy that you have worked on that has incorporated equity?

Resilience

7. How would you define resilience?
8. To what extent do you incorporate resilience into your everyday work? For example, are there resilience dimensions or metrics that you consider in your planning and decision-making processes?
9. Do you see resilience and equity being related to each other?
    a. If yes, are there any opportunities you can identify in your work that can connect the concepts? Or is this something you are striving for in your work?
    b. If no, why?

GI

10. How familiar are you with the concept of GI? Have you worked with the GI Branch before?
11. Have you ever considered GI as a solution or something that you can use to help you to meet your planning objectives? Or to achieve co-benefits in your work?
    a. If yes, how, and what areas of your plans or projects align with GI?
    b. If not, why? Are their communication or knowledge gaps hindering this?
10. What is the biggest lesson you have learned from integrating equity into your work that you would share with other departments trying to do the same thing?