Rethinking Public Transit Networks Using Climate Change Mitigation, Social Justice, and Climate Justice Lenses

A Greater Victoria Area Case Study

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Introduction

Transportation is a key policy area for climate change mitigation in Canada, with it being one of the country's largest sources of greenhouse gas (GHG) emissions (Environment and Climate Change Canada, 2022) It is also important policy area for making progress toward social justice and equity, as it is the second largest expense for Canadian households (Statistics Canada, 2021), and typically those in lower income brackets are impacted more acutely by transportation expenses (Agrawal et al., 2011). Accordingly, transportation could be considered a critical policy area for *climate justice*, a concept that frames the impacts from, and solutions to, climate change using a social justice lens (Schlosberg & Collins, 2014).

Climate justice is used as a concept for describing inequities around climate vulnerabilities and adaptation, with scholars arguing that those who are least responsible for producing GHG emissions are those who are most impacted by the effects of climate change (Goh, 2020; Running, 2015). Social justice considerations also surround the strategies used for reducing GHG emissions, as certain solutions for reducing GHG emissions may benefit some groups more than others (Bulkeley et al., 2013). For example, Moran (2023) identified how the CleanBC climate change mitigation strategy for the province of British Columbia, Canada, can result in inequities in terms of wealthier groups benefiting more from strategies for transitioning to green transportation options. Accordingly, transportation is a critical area for designing and implementing plans and policies that align with climate justice principles and objectives.

Exploring new options and configurations for transit networks to meet climate change mitigation and social justice objectives requires an analytical approach, which can be done via network analysis using geographic information system (GIS) software. This research project engages in such analyses, using the Greater Victoria Area (GVA) in British Columbia as a case study. The GVA is currently experiencing great shifts in population distribution, with many people settling in suburban and rural neighbourhoods that are located away from the urban core. Langford, a municipality in these suburban areas, was identified as the third fastest-growing city in Canada, according to the most recent census (Statistics Canada, 2022).

There is a need to redesign the current transit system in the GVA to adapt to the shifts in regional demographics and distribution, and a redesign process can provide a valuable opportunity for making progress toward climate justice in the transportation sector. Striving for such progress aligns with BC Transit's mandate, which has committed to significantly cutting emissions to meet the province's climate targets 2040, while also committing to making transportation affordable

and accessible to vulnerable and remote communities across the province (BC Transit, 2020). When read together, these two commitment areas reflect goals related to climate justice.

The objectives of this research project are three-fold:

- To develop an analytical approach to inform the design of new transit networks that align with climate change mitigation and social justice objectives in a rapidly growing urban metropolitan region (i.e., the GVA)
- To identify and compare three different transit network scenarios, which respectively align with objectives around (1) climate mitigation, (2) social justice, and (3) climate justice
- To engage regional government and transportation planners to identify the opportunities and challenges for improving the GVA transit network.

Methods

The research first developed a framework for analyzing and mapping new transit networks using social justice, climate mitigation, and climate justice lenses. This work involved a comprehensive literature review, using peer-reviewed and non-peer-reviewed sources that were published within the past 15 years. Combinations of 'public transportation', 'public transit', 'TOD', 'Sustainable transit planning', 'social justice', 'climate mitigation' and 'climate justice' keywords were used in the literature search. The main outcome of the review was a list of indicators for guiding the remapping of transit networks in ways that align with climate change mitigation and social justice objectives.

Once the indicator list was created, it was introduced at a workshop that gathered academics and practitioners from Royal Roads University and the Community Social Planning Council of Great Victoria. The workshop involves two main activities. The first activity involved examining the indicator list to determine what is relevant to the transit network remapping work. The second activity consisted of weighting the indicators to identify their relative importance for remapping the transit network with respect to climate mitigation, social justice, and climate justice scenarios.

The research then involved a network analysis and scenario mapping exercise. Spatial data were obtained for the indicators identified through the literature review and workshop. Network analysis and linear regression methods were used to develop zoning maps for the GVA, which are maps that capture the importance of different areas in the GVA in terms of how accessibility to public transit can support climate change mitigation, social justice, and climate justice objectives.

The current transit-accessible areas were identified using network analysis, with these being areas with bus stops located within 400m of residents as per BC Transit's (2014) standards. Then, maps of key inaccessible areas were developed for climate change mitigation, social justice, and climate justice scenarios by identifying spaces that are important for meeting objectives in these planning and policy areas but are not currently transit accessible. Using the inaccessibility maps, new routes were identified that increase transit coverage in ways that meet climate change mitigation, social justice, and climate justice objectives.

The research was completed with an examination of the new transit routes with respect to their implications for regional policy and planning. This work involved engaging local and regional government and transit planners in the GVA. This engagement consisted of one-on-one sessions with participants that began with a presentation on the methods and results of the study and then involved a discussion guided by the following questions:

- What are your thoughts on the proposed bus routes?
- What are the primary obstacles or challenges that could impede the successful implementation of these routes?
- Are there any key considerations for the communities or stakeholders that would be affected by the implementation of these routes?
- What would be required to implement the suggested transit network (e.g., infrastructure, partnerships, etc.)?

Five people participated in these sessions, and their affiliations are shown in Table 1.

Table 1. List of affiliations of the stakeholder participants

Participant	Affiliation
1	BC Transit
2	Capital Regional District
3	District of Saanich
4	Town of Sydney
5	City of Victoria

The indicators and their weights were shared with the participants in the engagement sessions. Participants were contacted via email following the sessions with requests for additional comments and to review the indicators to suggest different weights. The indicator list and their weights were revised accordingly.

The revised weights ultimately were very similar in value to the initial weights; therefore, the scenario mapping work was not redone. Regardless, the feedback on the indicator list are captured and presented in this report. Figure 1 displays the full methodological approach used for developing and finalizing the indicator list.

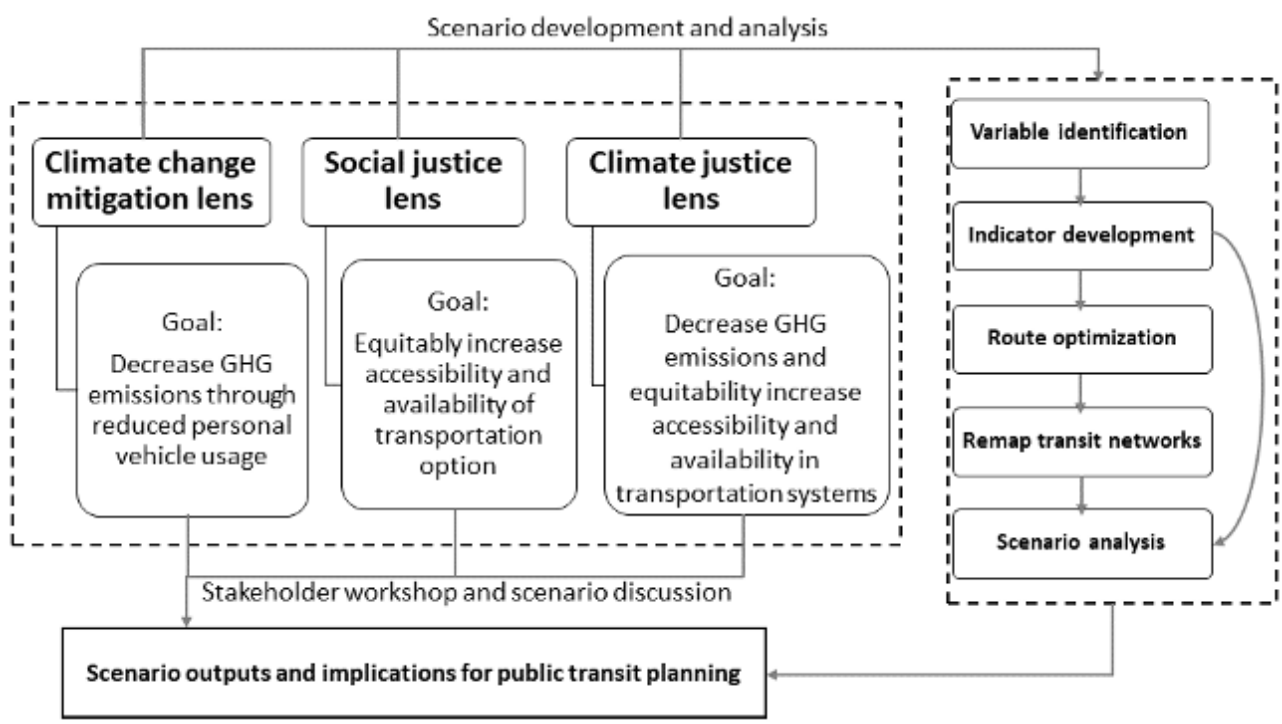

Figure 1. Methodological approach for redesigning the Greater Victoria Area transit network

Outcomes

Identifying the Indicators

Table 2 presents the list of indicators used for the redesign of GVA's public transit network, as per social justice, climate mitigation, and climate justice objectives. The indicators are organized into six themes: (1) transit network and diversity in travel modes, (2) accessibility improvement, (3) reduced emissions and habitat connectivity, (4) population density, (5) satisfaction with services, and (6) integrated land-use and transportation planning.

As shown in Table 2, the indicators were weighted with values between 0 and 1. The 'initial weights' column refers to the weights given to each indicator based on the Royal Roads University and the Community Social Planning Council workshop. The "revised weights" column captures the changes made following the stakeholder engagement sessions.

The indicators and weights were used to guide the network analysis and redesign of the transit network in accordance with the climate change mitigation, social justice, and climate justice scenarios. Each indictor in Table 2 is labelled (in parentheses) with an "A", "B", or "C": "A" refers to indicators that were used to develop the zoning maps; "B" refers to indicators used in the process of redesigning the transit networks; and "C" refers to indicators that merit consideration but (due to lack of data) were out of the scope of the study.

Table 2. Indicators for (re)designing a public transit network

Themes	Indicators	Notes	Weight					
			Climate mitigation		Social justice		Climate justice	
			Initial	Revised	Initial	Revised	Initial	Revised
1. Transit network and diversity in travel modes	1.1 (C) - Average trip distance	N/A	0.68	0.70	0.70	0.71	0.68	0.70
	1.2 (B) - Number of bus stations and lanes	N/A	-	0.10	0.60	0.64	0.60	0.63
	1.3 (B) - Transit accessibility to car parking facilities	N/A	0.43	0.43	0.48	0.50	0.50	0.50
	1.4 (C) - Integration of pedestrian and bike routes with public transit	N/A	0.69	0.73	0.70	0.74	0.68	0.72
	1.5 (B) - Transit mode diversity	N/A	0.77	0.77	0.77	0.77	0.77	0.77
2. Accessibility improvement	2.1 (A) - Accessibility for elderly groups	The percentage of elderly people in census tracts	-	0.09	0.60	0.65	0.70	0.73
	2.2 (A) - Accessibility for lower-income people	The percentage of people with lower than $40,000 annual income in census tracts	-	0.09	0.70	0.74	-	0.11

3. Reduced emissions and habitat connectivity	3.1 (C) - Carbon emissions by public transportation	N/A	0.71	0.66	0.70	0.63	0.63	0.58
	3.2 (B) - Proximity of Public Transit to Green Spaces	Priority of designing transit routes near green spaces	0.50	0.46	0.40	0.40	0.80	0.74
	3.3 (B) - Reduction of barrier effects	30 km/h speed limit for routes near habitats	0..47	0.44	0.40	0.35	0.40	0.36
4. Population density	4.1 (A) - Employment density	The percentage of employed people residing in the census tracts	0.80	0.81	0.80	0.81	0.90	0.90
	4.2 (A) - Population density	The population distribution among the census tracts	0.70	0.73	0.60	0.61	0.70	0.71
5. Satisfaction in services	5.1 (B) - Public transit affordability	N/A	0.80	0.83	0.90	0.91	0.93	0.94
	5.2 (B) - Bus wait time	N/A	0.20	0.30	0.50	0.56	0.53	0.59
6. Integrated land-use and transportation planning	6.1 (A) - Accessibility provision to recreation and entertainment amenities	Land-uses and build structures that accommodate recreational activities	0.70	0.70	0.60	0.61	0.67	0.67
	6.2 (A) - Accessibility to and connectivity among areas with different land-uses	• CM - Institutional, commercial, recreational, mixed-use land-uses • SJ - All land-uses included in the CM scenario, and an addition of charitable services (e.g., food banks and shelters) • CJ - Same as SJ	0.70	0.73	0.70	0.73	0.80	0.81

Sources: BC Transit, 2020; BC Transit, 2011; Bu et al. 2021; Giles-Corti et al. 2020; Mihyeon Jeon & Amekudzi, 2005; Tran et al. 2021; Wey, 2019; Yang et al. 2020; Naganathan & Chong, 2017; Munira & San Santoso, 2017; Kalifa et al. 2022; Sdoukopoulos et al. 2019; Mansourianfar & Haghshenas, 2018; Oeschger et al. 2020; Suria et al. 2019; Shiftan et al. 2003; De Gruyter et al. 2016; Seker & Aydin, 2020; Ogryzek et al. 2020; Illahi, & Mir, 2021; Wang et al. 2022; Lyu et al. 2016; Taki et al. 2017 ;Qiang et al. 2022; Huang et al. 2018; Motieya & Mesgari, 2018; Taki et al. b 2017; Maheshwari et al. 2022; Yu et al. 2022; Uddin et al. 2023; Sinha, 2003; Haghshenas & Vaziri, 2012.

Developing the Zoning Maps

The transit network mapping process began by creating zoning maps. The process involved first collecting spatial data related to indicators, and this was primarily done by accessing three sources: CRD Open Data, BC Transit Database, and Statistic Canada (census data of 2021).

Then, transit-accessible areas were identified using the 400m BC Transit standard (2014), and the network analysis was subsequently employed to examine the transit network with respect to the indicators. Figure 2 provides examples of the outputs of this analysis.

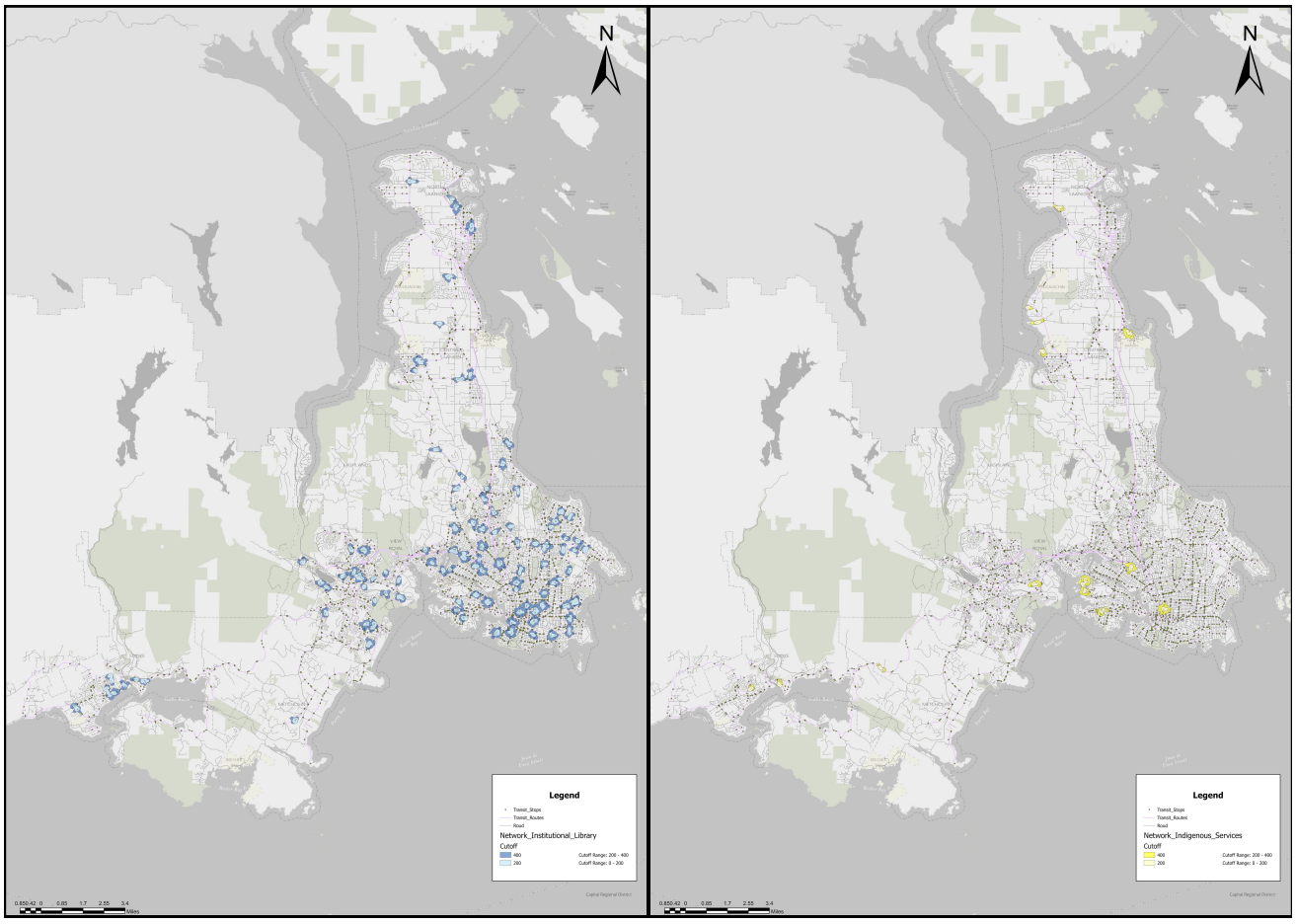

Figure 2. Network analysis for examining access to institutional locations (right map) and for Indigenous communities (left map) based on 200m- and 400m-service areas

Following the network analysis, a regression model (Equation 1) was used to calculate the importance of different locations for transit access as per the indicators and scenarios. In the model, "Y" is the importance of each location to the different scenario objectives, "β" is the weight of an indicator, and "X" is the presence of an indicator (i.e., if an indicator exists in a location, then X has a value of 1, otherwise X is 0).

Equation 1. $Y= \beta1X1+ \beta2X2 + \beta3X3 + \beta4X4 + \beta5X5 + \beta6X6 +.... BnXn$

After the regressions were conducted, the "importance values" (i.e., the Y values) were grouped into three main categories of low, medium, and high importance using a natural breaks method. Complete transit coverage across the GVA is not efficient or effective; therefore, the medium- and high-importance areas were prioritized during the redesign and remapping of transit networks.

Based on the analysis described above, "zoning maps" were developed for each of the scenarios to identify priority areas for redesigning the transit network in ways that improve accessibility. Figure 3 to 5 displays the zoning maps for the three different scenarios.

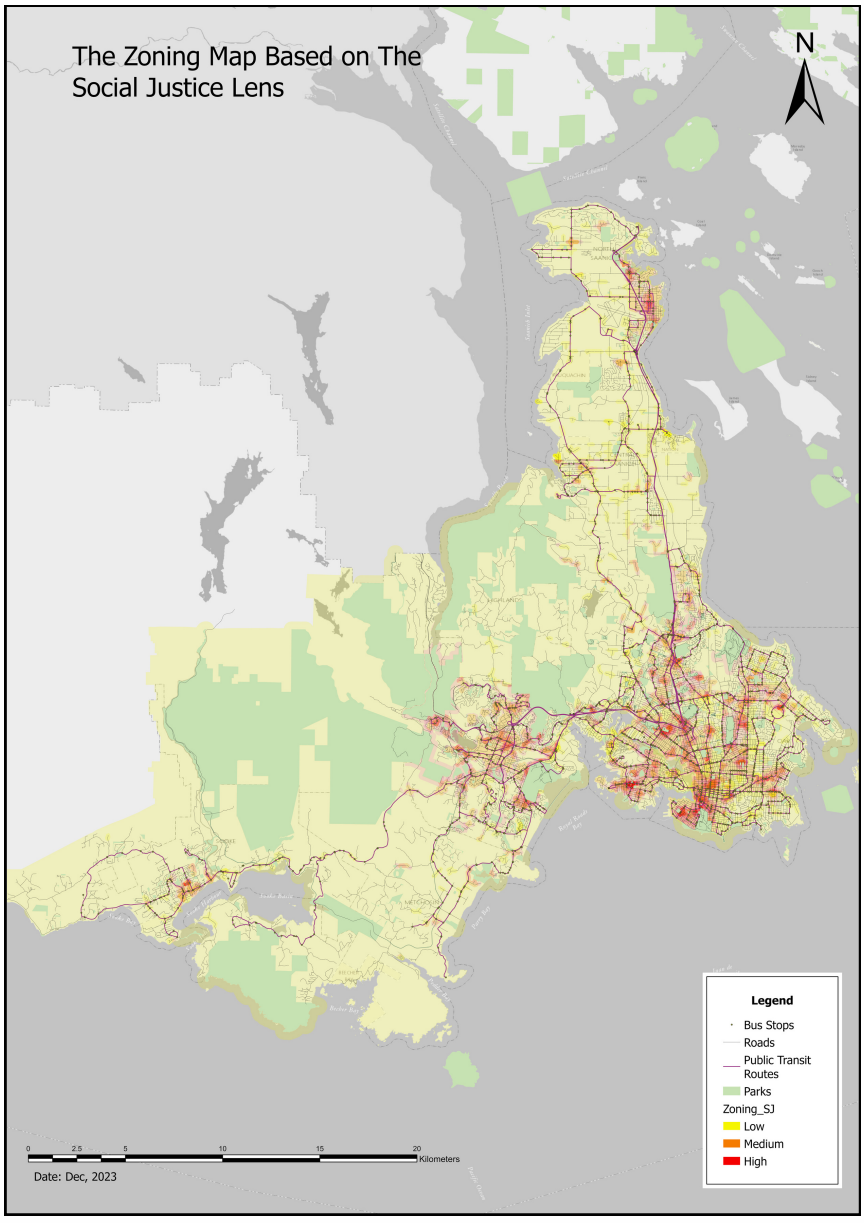

Figure 3. The zoning map for the social justice scenario

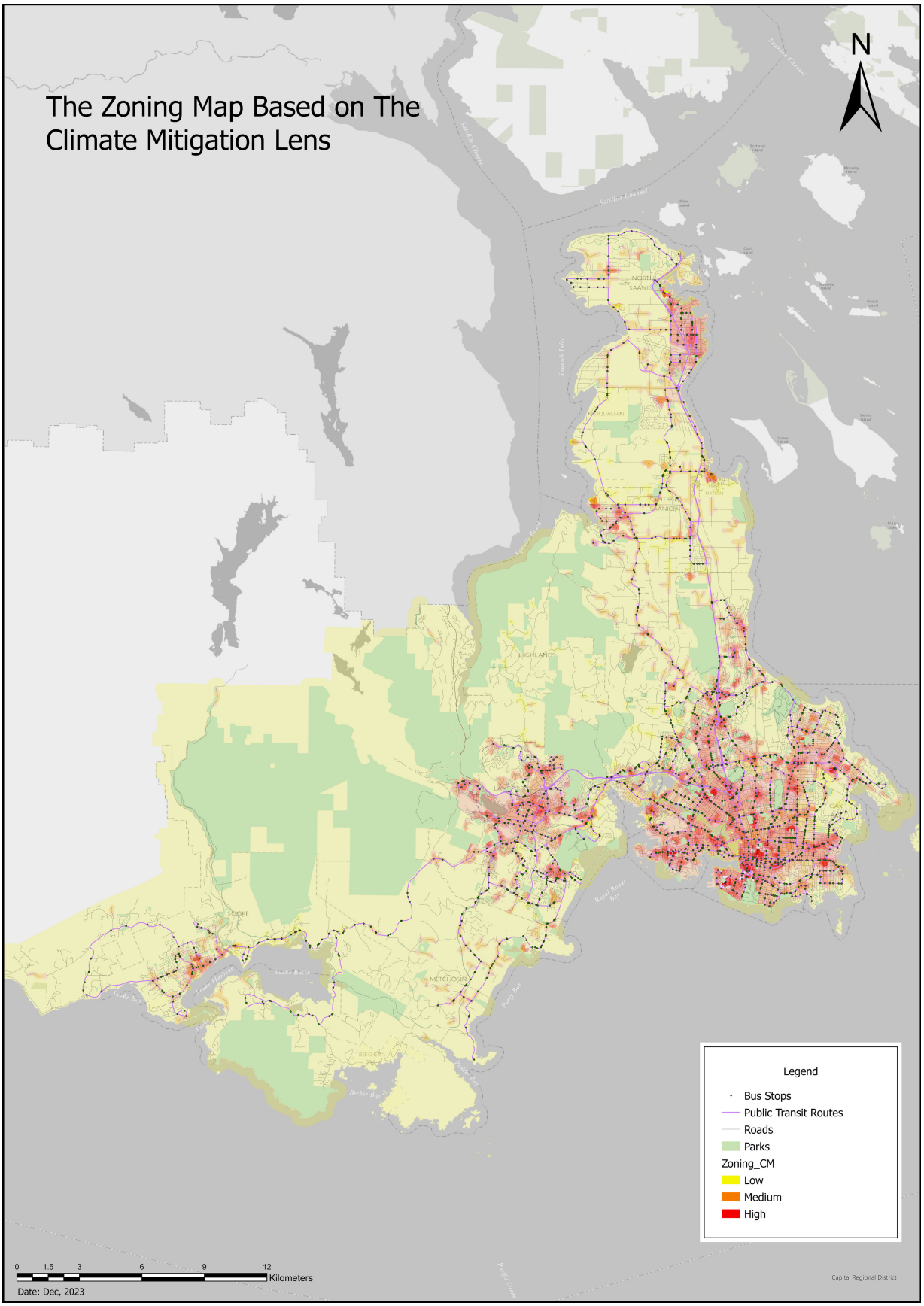

Figure 4. The zoning map for the climate change mitigation scenario

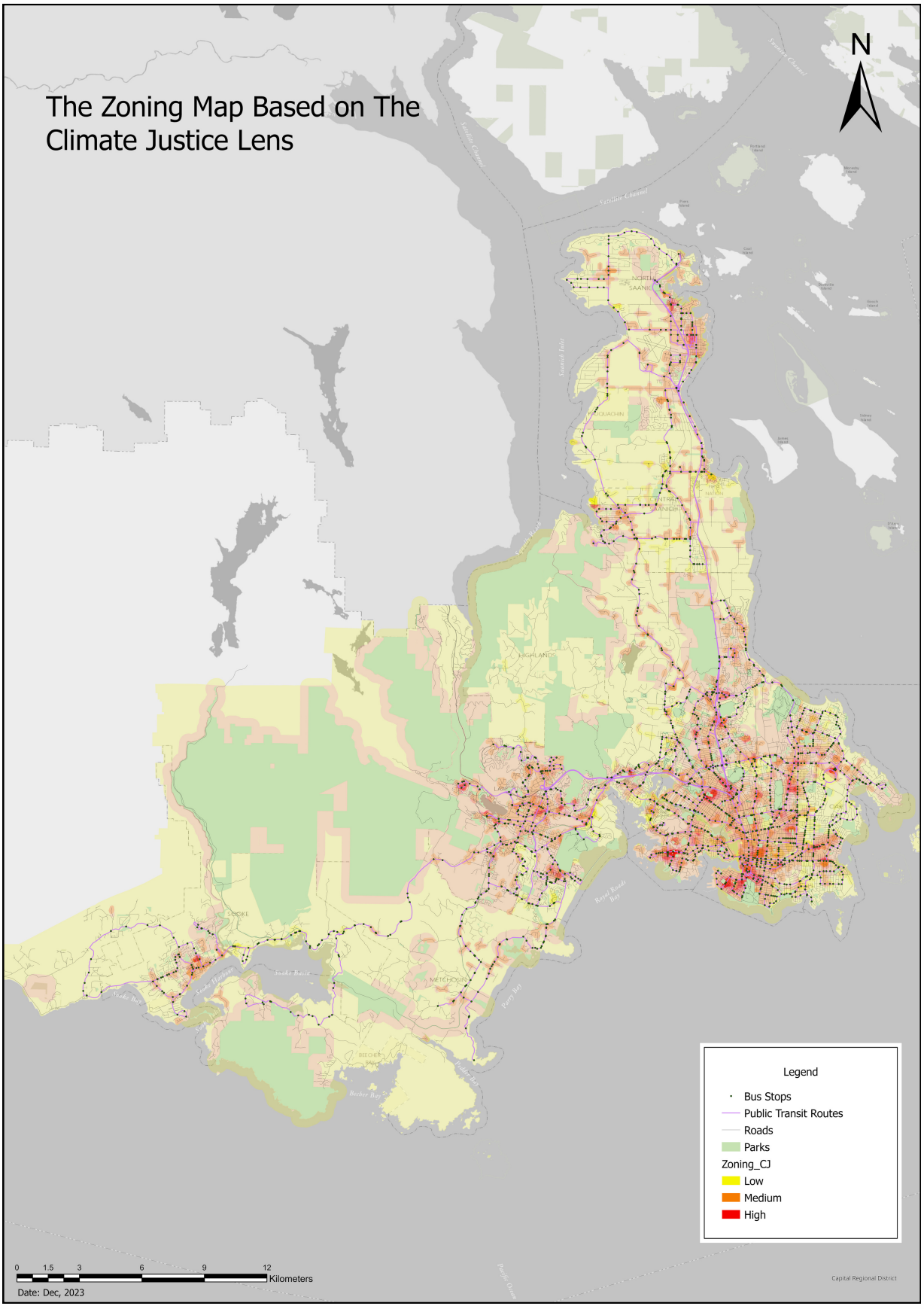

Figure 5. The zoning map for the climate justice scenario

Evaluating the Existing Transit Network

The existing public transit network was examined in terms of its coverage of the medium- and high-importance areas defined through the zoning maps. Network analysis was used, involving a 400m service area around the existing bus stops (see Figure 6). The analysis then involved identifying medium- and high-importance areas that do not currently have transit coverage (see Figure 7 to 9).

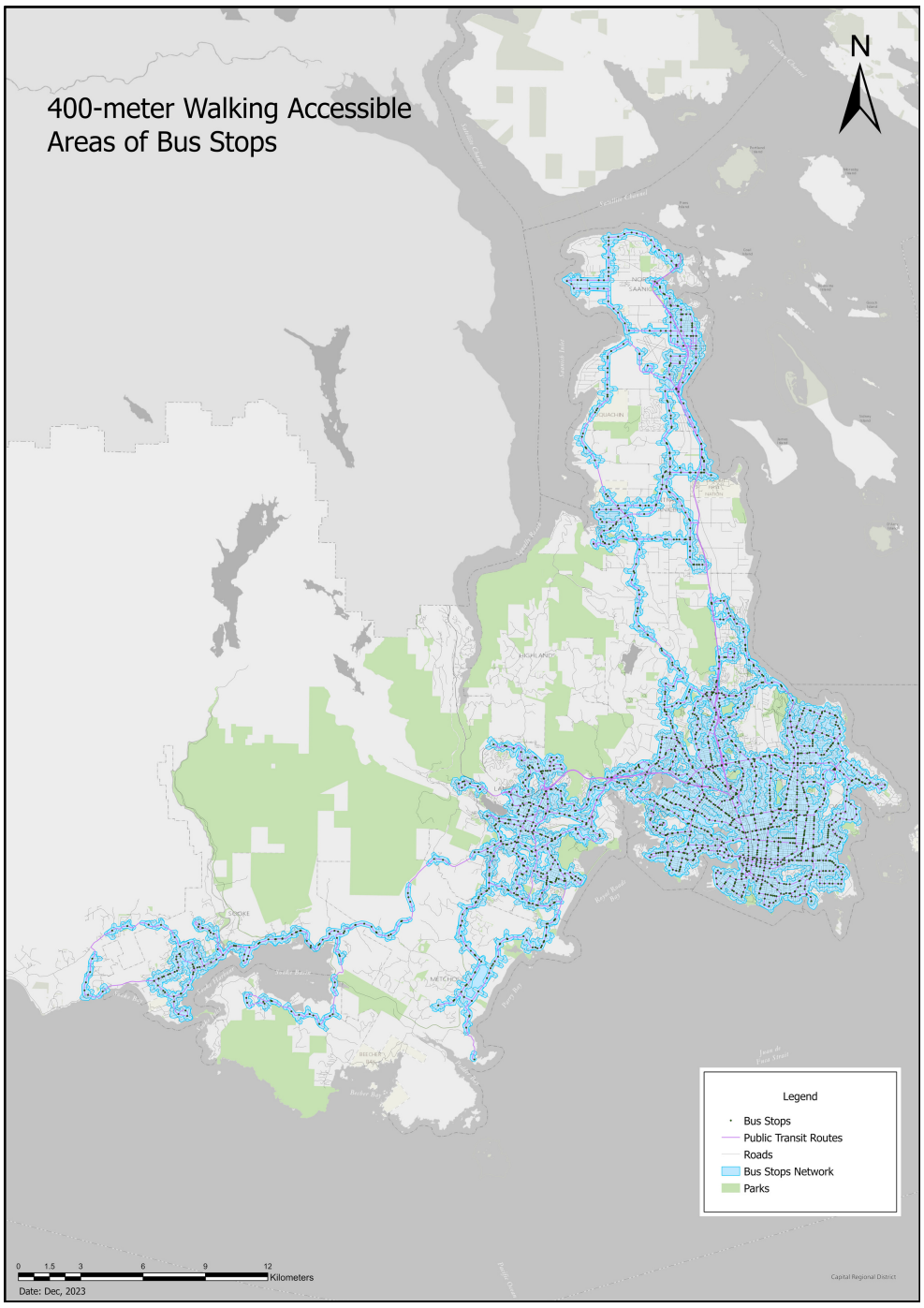

Figure 6. Bus stops in the GVA and a 400m service area

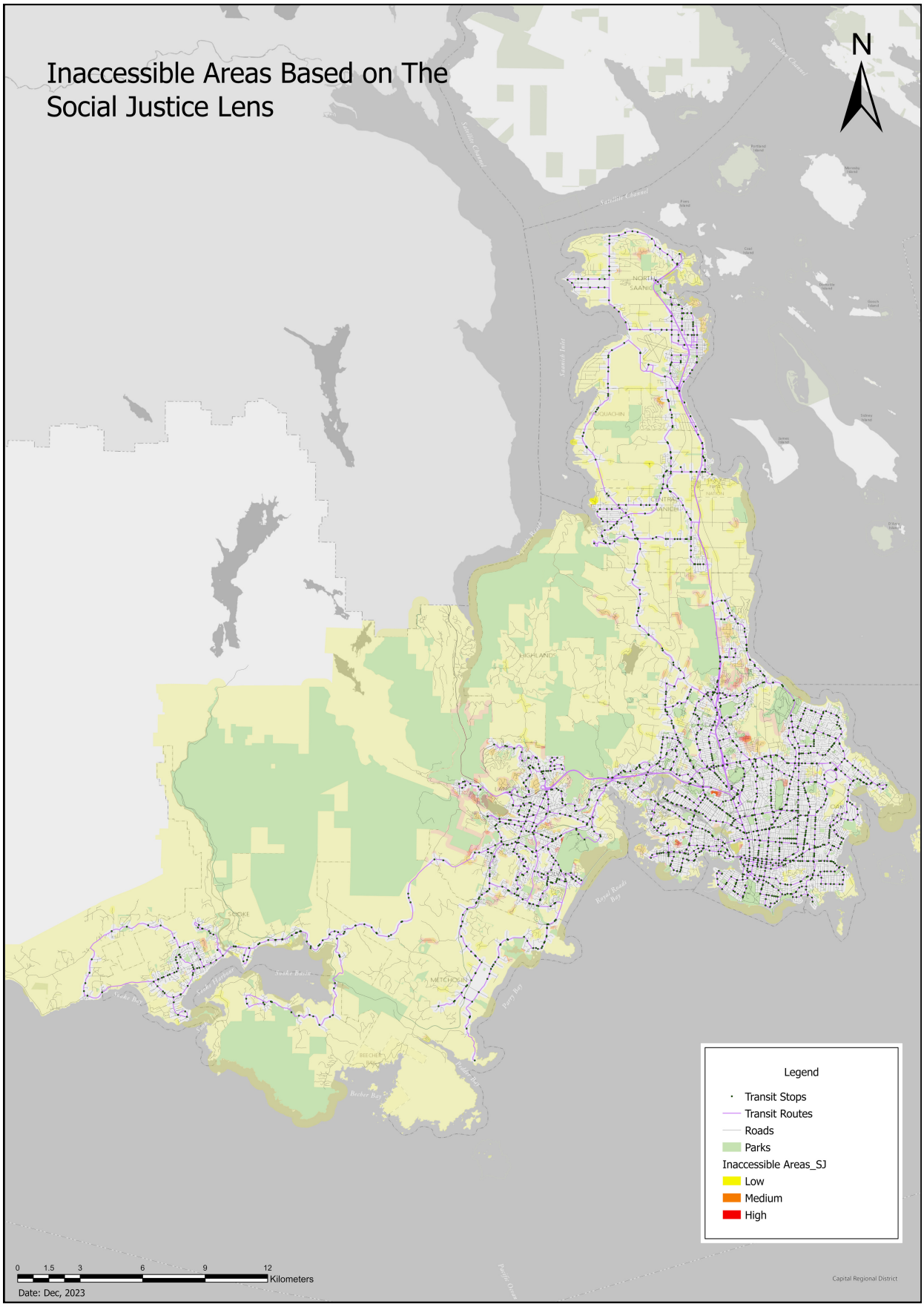

Figure 7. Public transit inaccessibility in the social justice scenario

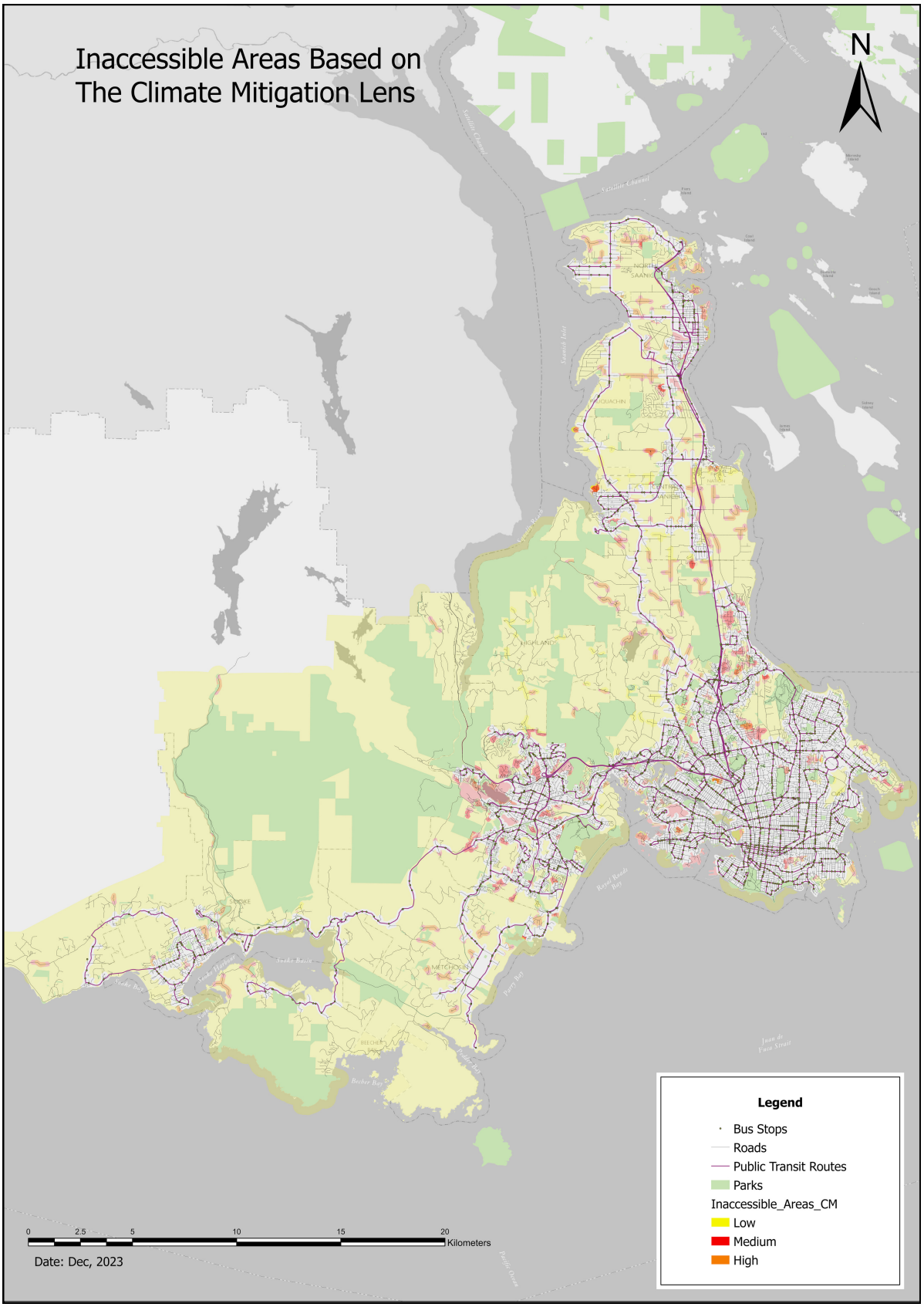

Figure 8. Public transit inaccessibility in the climate change mitigation scenario

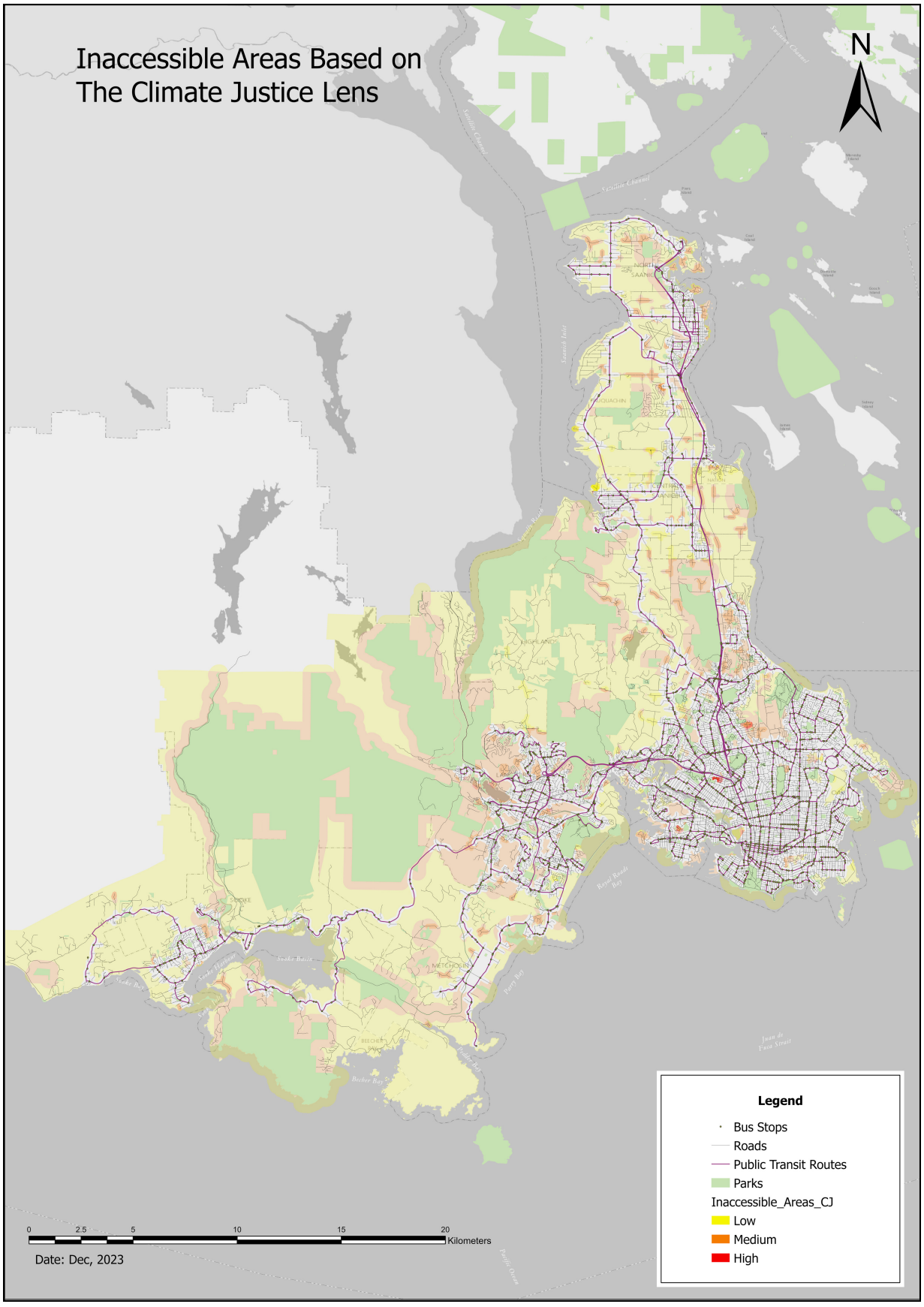

Figure 9. Public transit inaccessibility in the climate justice scenario

Proposed New Transit Networks

The analysis identified new potential public transit routes and stops that improve coverage across currently low-access areas. A few considerations were involved in the development of these new transit networks. One such consideration is that the design of the GVA public transit network should optimize efficiency and accessibility. Accordingly, it is best to leverage existing infrastructure to its full potential to improve sustainability outcomes while minimizing the need for extensive new construction.

Transit accessibility also includes considerations around how convenient it is to park near bus stops to enable better multi-modal travel that involves both private vehicles and public transportation. This is a particularly important consideration with respect to major transit hubs.

The proposed networks were strategically designed to improve accessibility in areas identified as high- and medium-importance in accordance with the zoning maps. By aligning transit routes with zoning classifications, the transit system serves the specific needs and priorities of different regions, creating an effective and well-connected public transit network for the GVA.

Table 3 describes how the proposed transit networks were designed, and maps of these networks are displayed in Figures 10 to 13. The table also includes suggestions for improving the transit system that are aspatial in nature and emerged from the discussions in the stakeholder engagement work.

Table 3. Proposed redesigning the public transit network based on the scenarios

Scenario	Improvement area	Suggestions
Climate change mitigation	Transit network	Suggestions for the bus routes involve two new bus routes (see suggestion 1 and 3 in Figure 6), one change in the length of a line to improve its service area coverage (see suggestion 2 in Figure 6); one new bus stop (see suggestion 5 in Figure 6); and three changes in a part of two existing bus routes (see suggestion 4, 6, and 7 in Figure 6).
	Transit frequency	Suggestions are based on population density. • 15 minutes for more than 2,804 people per km2 population density areas. • 20 minutes for 1,024-2,804 people per km2 population density areas. • 30 minutes for other areas.
	Transit type	All buses should transition to electric vehicles (EVs).
Social justice	Transit network	Suggestions involve two new bus routes (see suggestions 1 and 2 in Figure 7); one new bus stop (see suggestion 4 in Figure 7); and two changes in a part of two existing bus routes (see suggestions 3, and 5 in Figure 7). Two BRT routes from downtown Victoria to Swartz Bay and Sooke destinations are suggested to provide fast and affordable accessibility (see blue lines in Figure 7). To increase the usage of the BRT lines, their stops are located near parking lots to give users multimodal transportation options..
Social justice	Transit frequency	Suggestions are based on the percentage of the households with income lower than $40,000/year. • 15 minutes for areas where more than 38% of their populations have lower than $40,000/year income. • 20 minutes for where between 33-38% of their populations have lower than $40,000/year income· • 30 minutes for other areas.
	Transit type	Not applicable
	Others	Subsidy policies that provide bus tickets for lower-income and elderly people should be adopted.
Climate justice	Transit network	A mixture of suggested bus routes for the climate mitigation lense and two BRT routes for the social justice lens are suggested, as shown in Figure 8.
	Transit frequency	Suggestions are based on population and income variables, and they combine the features of both the climate change mitigation and social justice scenarios.
	Transit type	All buses should transition to EVs.

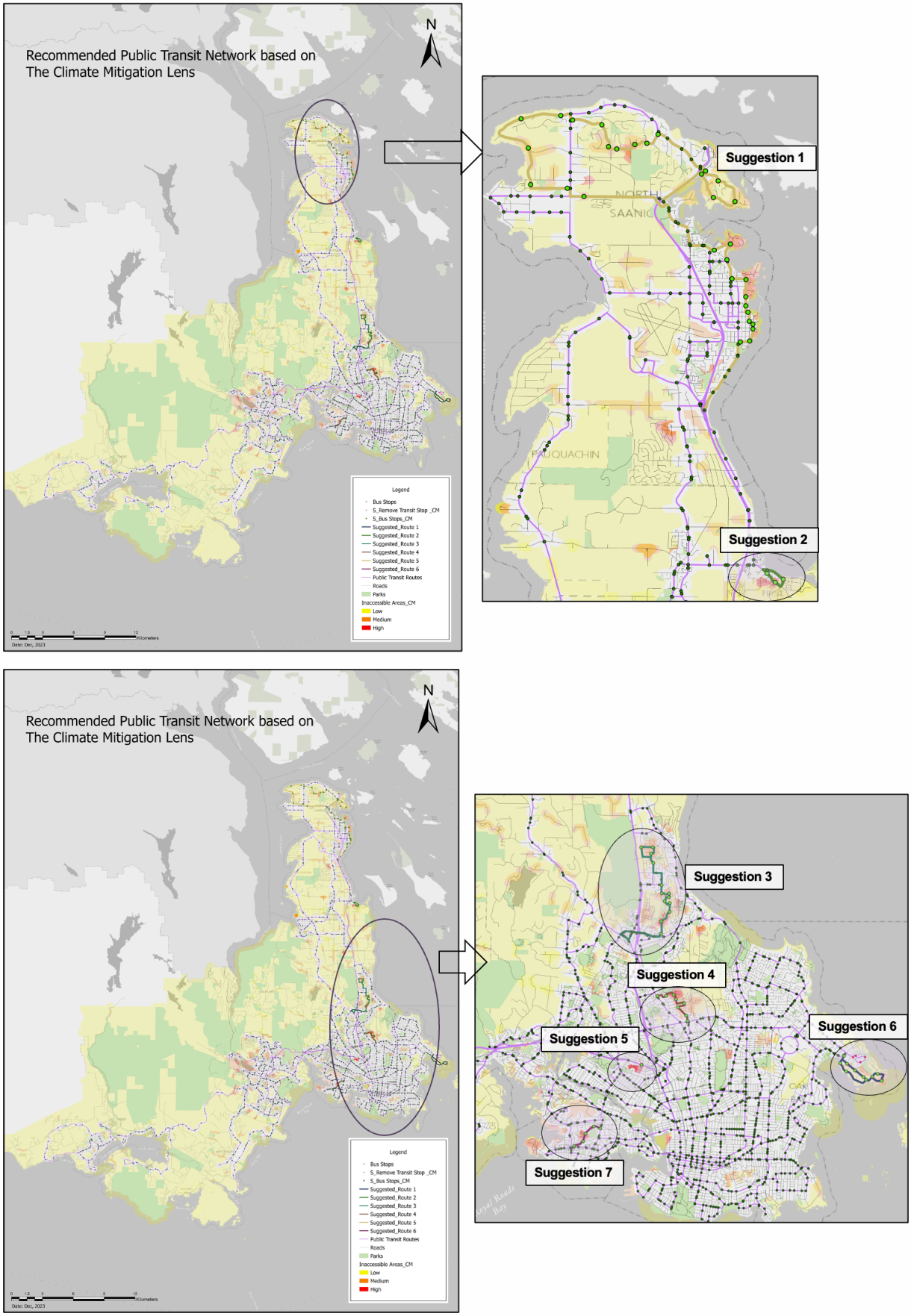

Figure 10. Redesigning the transit network based on the climate change mitigation scenario

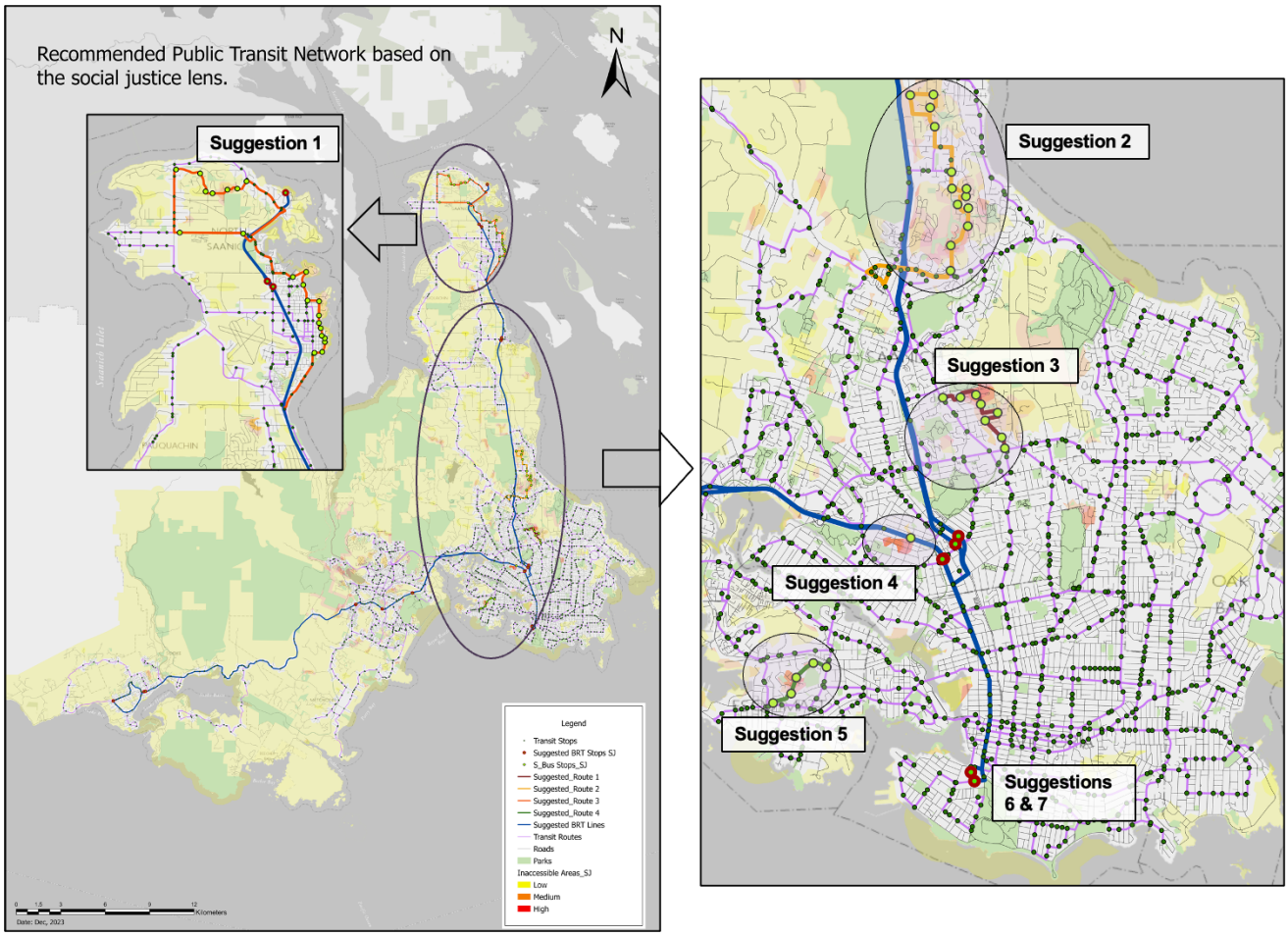

Figure 11. Redesigning the transit network based on the social justice scenario

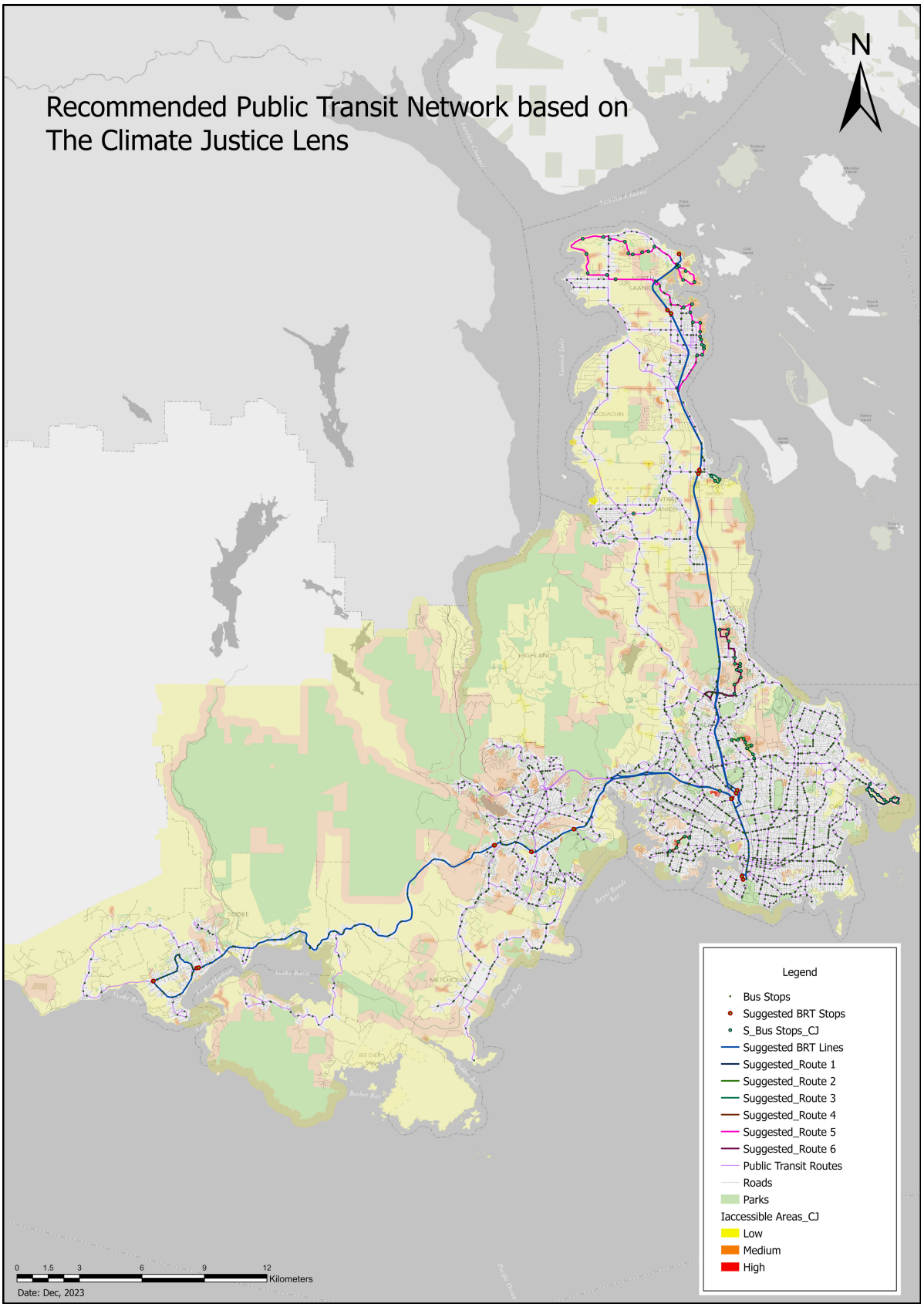

Figure 12. Redesigning the transit network based on the climate justice scenario

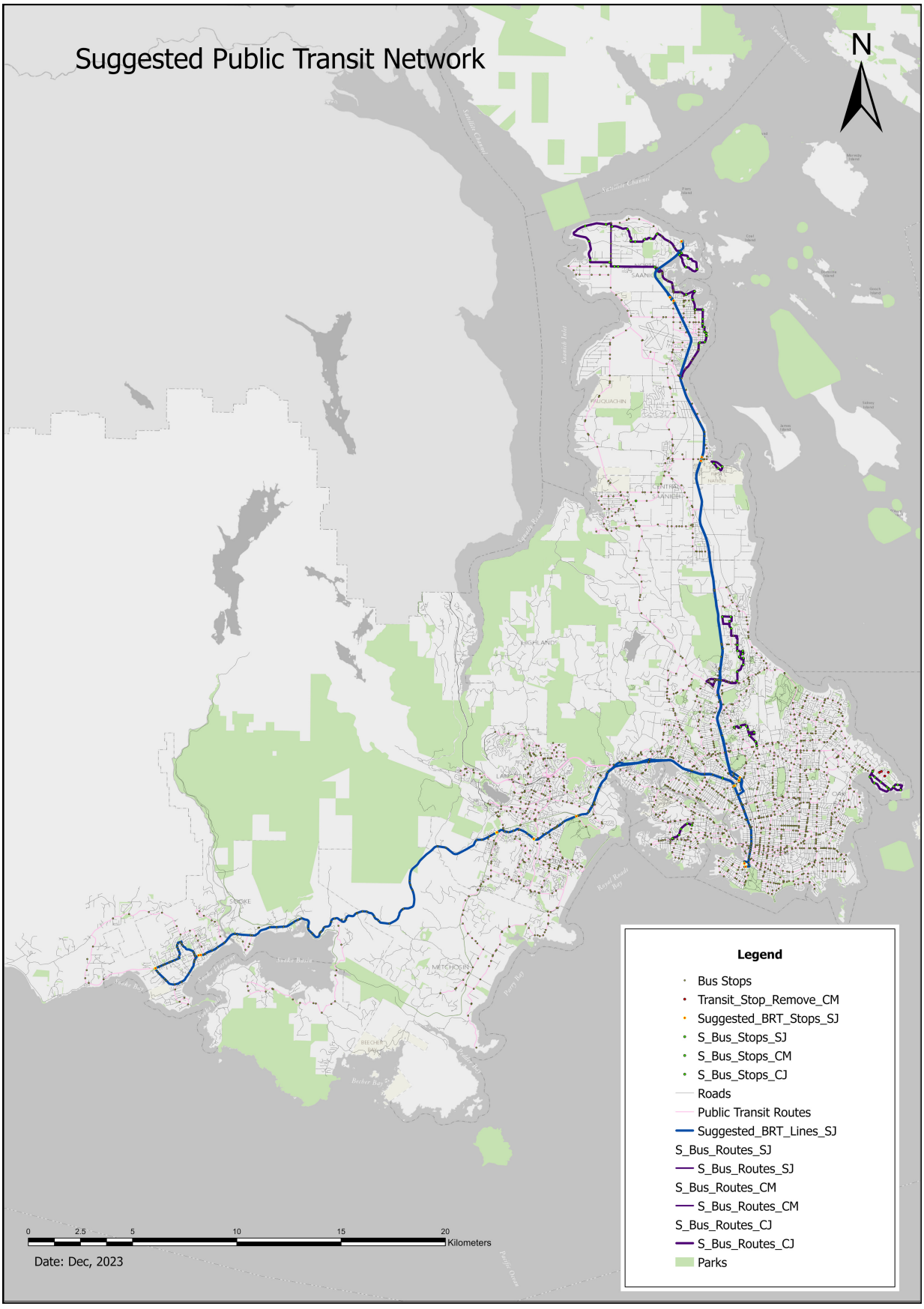

Figure 13. Overall recommendations for redesigning the public transit network in the GVA

Tool Development

GIS tools were developed through this work using Model Builder in Arc GIS Pro. When applied to the appropriate spatial data, these tools can reveal areas of low transit accessibility, which need improved coverage in order to meet climate change mitigation and social justice objectives. Local government and transit planners can use these tools and GIS models for future studies to help improve their respective transit networks. The tools can be found on the project website:

www.triaslab.ca/climate-justice-transit

Opportunities and Challenges

The stakeholder engagement sessions revealed a series of opportunities and challenges for the implementation of the proposed transit networks. These findings are discussed here, and organized into four categories: governance, planning, climate action, and social justice.

Governance

Transit decision-making authority lies with the Victoria Regional Transit Commission, which is comprised of eight officials appointed by the province to represent local governments. Transit funding involves a provincial contribution of 31.7%, with the remainder of the funds sourced locally through property tax levies, passenger fees, advertising revenues, and fuel tax. The Victoria Regional Transit Commission aims to balance regional equity and density considerations when allocating transit funding and resources. Financial challenges and funding constraints have resulted in the prioritization of existing service demands and issues over expansion plans. Such priorities include enhancing rapid bus service, increasing the frequency of highly-used transit routes, and collaborating with municipalities on their community plans.

The stakeholder engagement sessions done in this research revealed that collaboration with the municipalities in the GVA is critical for developing effective public transportation. Such collaboration involves discussions and decisions on bus stop locations and transit infrastructure enhancements. Challenges related to road width and infrastructure guidelines in specific areas are also covered in these discussions.

Stakeholder engagement is done prior to implementing significant changes in the public transit system, and there are ongoing consultations with School Districts, Island Health, and other stakeholders to gather input and feedback on suggested changes. The Accessible Transit Advisory Committee is a key stakeholder in this

engagement, as it provides valuable advice on accessibility issues. Accordingly, the maps produced through this research could be useful tools when examined by such committees, and they could be shared in engagement sessions to stimulate thinking on how to improve transit systems in ways that result in climate change mitigation and social justice outcomes.

It is worth noting that one stakeholder participant engaged in this research was highly critical of the indicator list and the research process. The participant indicated that it would have been better to engage the stakeholders prior to developing the initial indicator and weightings list, rather than developing this initial list via the Community Social Planning Council and Royal Roads University workshop. Such comments demonstrate the importance of carefully considering how engagement is done in transportation planning, both in terms of planning practice and research that is designed to support planning processes.

Planning

Transportation planning involves thinking about how to facilitate multiple modes of travel, which raises questions about who benefits most in terms of have access to buses and alternative modes of travel. In addition, public transit planning can both influence and respond to trends in residential populations and car ownership, which hold implications for the design of the overall transportation network. For example, the design of the Westshore transit network (as can be seen in Figure 13) signifies a strategic response to evolving density dynamics, but implementing this route requires additional funding.

Balance is needed between attracting new ridership and optimizing routes for existing commuters. This presents challenging considerations regarding whether routes should be strategically designed to draw in new riders or to enhance existing routes that serve the current regular daily commuters, a challenge that is referred to as the “chicken-and-egg conundrum.” It is also worth considering how transit and land-use plans affect one another. Planners should thoroughly examine the implications of introducing (for example) new transit hubs and routes with respect to proposed changes in land uses and zoning before proceeding with the implementation of a transit plan.

The stakeholder engagement sessions demonstrated that different understandings and definitions of public transit accessibility exist. A regional government participant, whose work involves GHG accounting and climate plan implementation,

noted that accessibility requires bus stops to be within a 15-minute walk of residents. However, a municipal government climate action participant considered a 150m walking distance to bus stops as the best accessibility measure since this distance provides accessibility for all groups including women with children and elderly people. Furthermore, BC Transit considers a 400m accessibility for more than 85% of residents as an adequate measure of accessibility (BC Transit, 2014).

Climate Change Mitigation

Transportation is a significant contributor to GHG emissions, and the goal of reducing GHGs in this sector through a shift to sustainable transportation requires implementing a variety of strategies. Such strategies include increasing opportunities for active modes of transportation, improved public transit, shared mobility solutions, and EVs. As identified by stakeholders who participated in this research, these strategic areas are "key pillars" in improving local transportation in ways that reduce personal vehicle GHG emissions.

Social Justice

When designing transit networks to align with social justice objectives, demographic considerations are critical, particularly strategies that reduce transportation costs for groups like low-income people, seniors, and individuals with disabilities. Programs such as e-bike incentives for low-income households can be implemented as part of a comprehensive approach to climate-friendly transportation solutions. However, the effects of these programs on shifting transportation behaviours within these demographics should be measured to ensure that they are actually producing benefits.

Some bus routes that may not yield significant climate benefits due to lower ridership could still play an important role in social justice by providing essential transportation services to certain communities, such as routes that provide service to First Nation communities. Such routes may not contribute substantially to climate action goals due to how the serve lower population bases; however, they are important in terms of social justice and equity, demonstrating how climate change mitigation and social justice objectives do not completely align in public transit network design work. It is also worth noting that social justice considerations also involve engaging and gaining permission from First Nation communities before implementing routes and building infrastructure in these communities.

Conclusion

This research effort involved developing and examining scenarios for redesigning the public transit network in the GVA. The research produced useful insights regarding how to develop such networks in ways that address climate change and social justice issues and objectives. The study employed an analytical framework and GIS toolset to map and assess three regional transit scenarios that respectively align with climate change mitigation, social justice, and climate justice objectives.

The stakeholder engagement sessions done in this research revealed that challenges exist with respect to implementing the proposed route changes identified in this study. Such challenges include financial resource constraints, particularly in terms of adding new routes and transitioning to EVs.

Findings from the stakeholder engagement work also presented key considerations around universal accessibility to public transportation. Transit accessibility for marginalized groups was considered to be particularly important. In addition, transit access to First Nations communities was identified as important, regardless of whether it contributes to climate action objectives. However, it is worth noting that engagement with (and obtaining permission to build transit infrastructure from) First Nations communities is integral to the implementation of such transit routes.

This research produced practical insights into the challenges and considerations for the successful implementation of an improved public transit system as per climate change mitigation and social justice objectives. When developing transit systems, planners and decision-makers should focus not only on technical aspects of these systems, but also on fostering partnerships and ensuring an equitable distribution of the benefits of public transportation systems. Such a comprehensive approach will better result in community-wide sustainability outcomes and progress toward a range of social and environmental goals.

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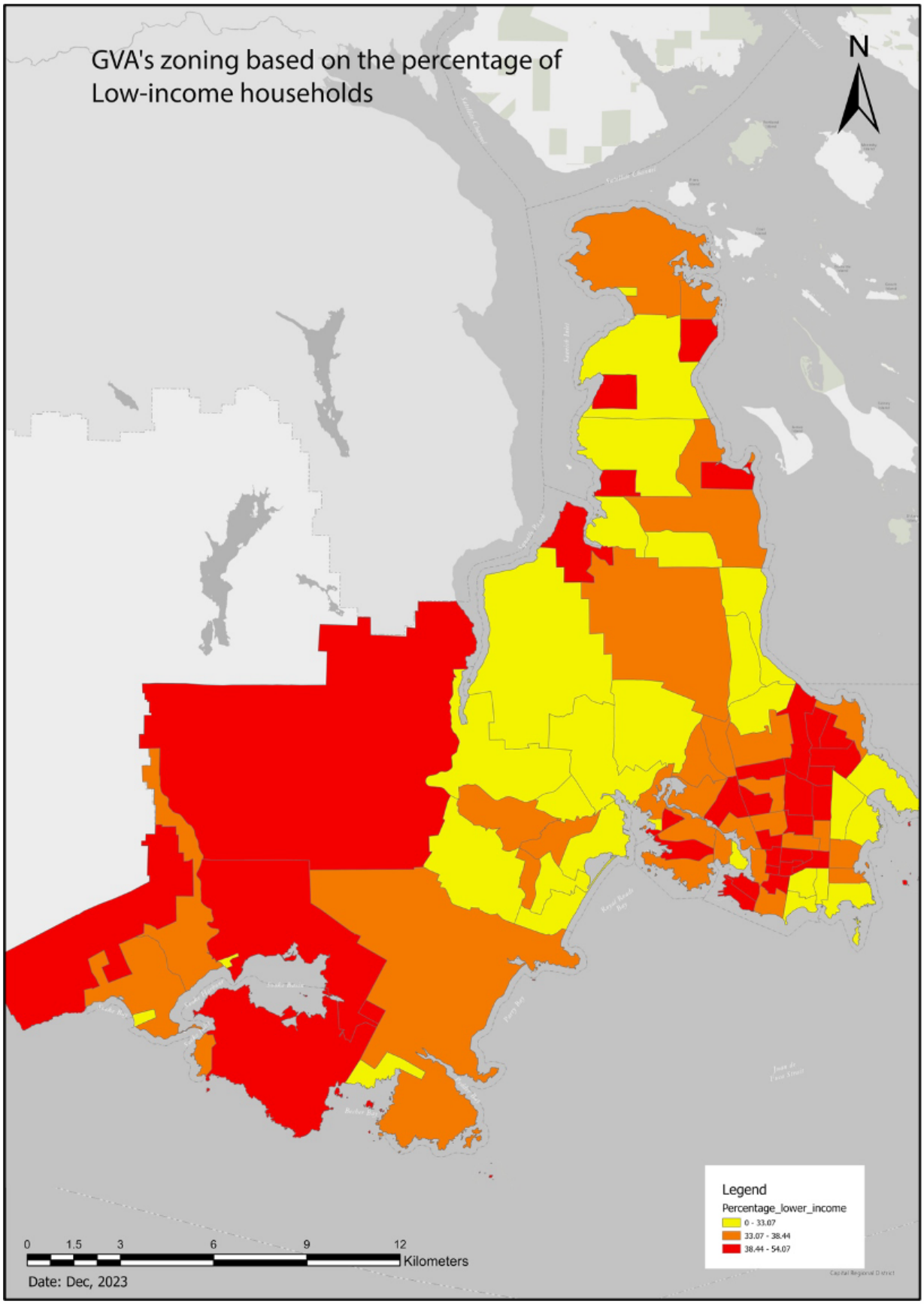

Figure A. Percentage of households with income lower than $40,000/year

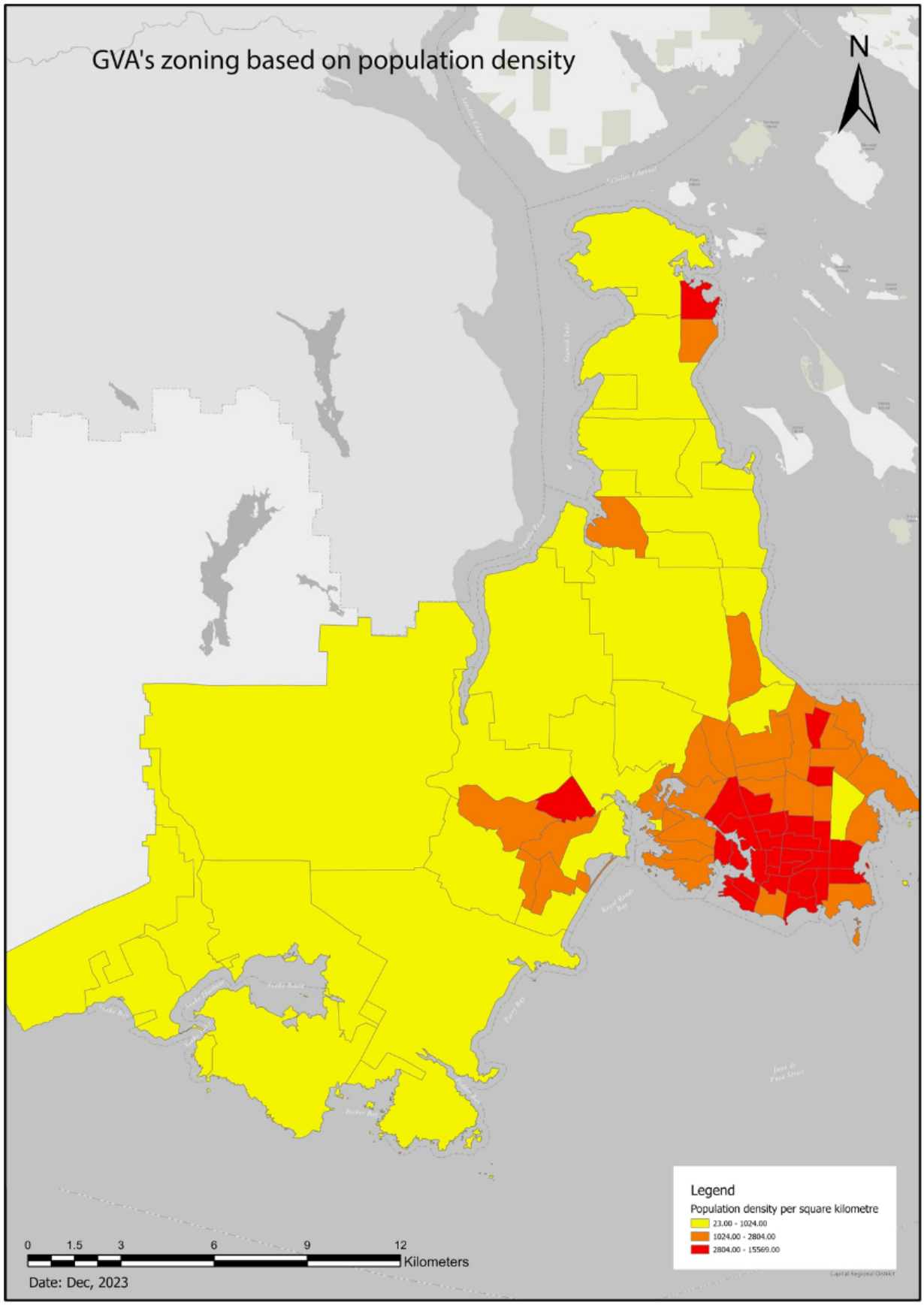

Figure B. Population density