Community systems models and development scenarios for integrated planning: Lessons learned from a participatory approach

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Systems models can support community planning, and by engaging local government and community stakeholders, these models can be designed to capture a comprehensive but manageable range of key interests, concerns and values. This study explores a participatory approach for designing a community systems modeling exercise. The research involved convening focus groups of local government and diverse community stakeholders in Squamish, Canada, in order to discuss local issues and possible futures for the community. Focus group feedback was used to inform the development of a model illustrating relationships between development paths (reflecting different densities) and multiple community outcomes, such as access to amenities and education, walkability, parks/trails, food and farm systems, public transit, housing affordability and local employment. A participatory approach to modeling yielded many benefits, including alignment with normative participatory planning concepts, effective model scoping, accessing additional information sources, and enhancing local social capital and investment in the project.

1. Introduction

Community planning is a complex process that requires understanding the relationships between, and implications for, human and ecological systems. Planners must work with citizens to optimize land use in order to achieve desired future conditions (Sheppard et al., 2011). These optimal future conditions are often defined to be ‘sustainable’, in that they reconcile social, environmental and economic imperatives (Dale, 2001). Due to the complex and interdisciplinary nature of community planning, sophisticated models can be used to help guide decisions at many scales. These models are often used to examine the implications of scenarios, meaning they illuminate a range of potential conditions that could result from implementing particular policies and plans, and/or developing local land in different ways (e.g., residential, commercial, mixed-use, agricultural, etc.). For example, Salter et al. (2009) supported community planning efforts by presenting potential outcomes of different residential density scenarios to local government and residents of Bowen Island, Canada. These scenarios provided the community with insights on the implications of densifying development with respect to factors such as water available, local population change, energy usage and waste generation.

Systems modelling can be a powerful tool in community planning. Generally speaking, a systems model can be considered to be a representation of a group of interrelated elements. These elements, which are often represented quantitatively, may be strictly physical or technical and/or include human or social factors (Checkland, 1983). Systems models have been used to guide a host of different local decisions, ranging from transportation development (e.g., Bargh et al., 2012), climate change adaptation (e.g., Picketts et al., 2012) and agricultural decisions (e.g., Woodward et al., 2008). Almeida et al. (2009) describe urban systems models as models that build up from behavioural basics (i.e., predicted human actions in various settings) to test the individual and, more importantly, aggregated effects of different land-use policies and infrastructure-related actions, an example being a model that examine greenhouse gas emissions effects including the influence transportation network conditions have on travel behaviours. Urban systems models are based on the established idea that there are significant similarities regarding the way people behave in an urban environment despite the considerable differences between them (Barthelemy, 2016). When expanding these models to capture complex relationships between multiple systems, they can be used to support integrated planning because they can reveal how certain strategies, policies and/or plans can benefit or impact a variety of community aspects and goals (Dale, 2018; Newell et al., 2018). For example, model outputs can reflect a suite of decisions and aspects of community including transportation effectiveness, land use efficiency, energy consumption, water usage and conservation, and/or local production of greenhouse gas emissions (e.g., Eluru et al., 2008; Frank et al., 2009; Salvini and Miller, 2005; Sperling and Berke, 2017; Wagner and Wegener, 2007).

Systems models must take into account a suite of decisions, feedbacks, influences and behaviours in order to be effective planning tools, and thus there is great uncertainty about what should be included and at what spatial and temporal and spatial scale they should be applied. Practitioners and researchers must attempt to balance the need to consider a range of interconnecting factors with the limits of information and the models themselves, while at the same time, producing useful knowledge for decision-makers. There must be compromises, and the outputs are always limited; however, models can still provide valuable information, test assumptions and give us insights into the implications of different decisions.

The decisions regarding what to model and how to best represent information that reflects complex interactions between humans and the environment in models are challenging. Given this reality, some scholars assert that determining what to model is best done in close partnership with the people who engage in these environments, specifically local stakeholders (e.g., Meliadou et al., 2012; Prell et al., 2007; Woodward et al., 2008).

Jentoft and Chuenpagee (2009) argue that the governance of a place or resource is most effective when done in cooperation with those that experience its associated problems and opportunities. In addition, processes that explicitly include stakeholder input are believed to increase buy-in, support for, and ultimately implementation of the resultant plans and strategies (e.g., Raymond and Brown, 2007; Robinson et al., 2011; Sheppard et al., 2011). Other benefits include enhanced social learning and social capital simply through convening the diverse stakeholders, and possibly contributing to new network formation (Dale and Sparkes, 2010; Newman and Dale, 2005). Stakeholder participation is an essential component of community planning, as it ensures a plan is grounded in local realities and social, cultural, political, economic and environmental contexts (Ling et al., 2009).

As participation is essential to community planning, it is also an important component when exploring potential community development scenarios (Amer et al., 2013), and this applies to both the design and assessment of these scenarios. In a similar vein, previous research has found stakeholder engagement useful for creating systems models that illustrate relationships and interactions when considering environmental management approaches (Prell et al., 2007; Woodward et al., 2008). Accordingly, this paper argues that participation is an essential component in the complicated work of modelling community systems and defining scenarios, and a necessary challenge to address in order to develop better tools for supporting integrated planning, and ultimately more sustainable community development.

This paper references (and contributes to) research on the use of urban systems models for planning (e.g., Almeida et al., Eluru et al., 2008; Salvini and Miller, 2005); however, it instead uses the term 'community systems model'. The reason for employing this terminology is to provide broader framing for model and scenario development, enabling a process that allows local government, stakeholders and community members to explore elements and relationships that extend beyond what is typically considered associated with 'urban systems', such as infrastructure associated with transportation, water, energy and food (Sperling and Berke, 2017). 'Community systems' can include these types infrastructure elements/relationships, but they can also refer to broader social, economic and cultural considerations, such as local aesthetics, sense of community, recreational opportunities, tourism and employment, etc. (e.g., Chan and Huang, 2004; Foster-Fishman et al., 2007). This paper does not intend to examine and articulate distinctions between urban systems and community systems models; however, it specifically uses the latter term because it frames the modelling process as one that aligns with participatory approaches to local planning.

This paper reports on a study conducted in Squamish, British Columbia (BC), Canada that used a participatory process for guiding the design of a systems model and scenario modelling exercise. The study explored ways of ensuring that community scenario modelling best reflects the most relevant local values and information, as determined by a diverse representation of stakeholders. The process was specifically designed to determine what factors to incorporate in community systems model and what scenarios to test. This work supports a second stage of research that focuses toward a more comprehensive integrated modelling approach.

2. Research Context

This study is part of a greater research project entitled *Spaces, Places and Possibilities*, which explores the use of system modelling and visualization techniques to better capture and convey potential outcomes of social and physical infrastructure decisions to local government and stakeholders. The research takes a scenario planning approach (Amer et al., 2013), meaning it models and visualizes aspects of 'potential futures' that could result from developing the community in a particular way. More information on this research project can be found on its webpage: https://www.crcresearch.org/spaces-places-and-possibilities

Spaces, Places and Possibilities involves three phases: (1) designing a community systems model and defining community development scenarios, (2) using the systems model to calculate/estimate possible social, economic and environmental outcomes of the scenarios, and (3) creating realistic, interactive visualizations depicting the scenarios, similar to those studied in Newell et al. (2017a,b). This paper reports on the first phase of the research, and it details a participatory process used to develop the systems model and community scenarios. The second and third phases of the research will be documented in forthcoming publications; however, the second phase has been completed and more information on this work can also be found in publicly available community reports (Newell and Picketts, 2019a,b).

2.1 Study site

Squamish is a town of 20,000 people located approximately 50 kilometres north of Vancouver on the traditional territory of the Squamish Nation. Squamish has a very complex and interesting geography due to many factors, including its situation at the end of Howe Sound Fjord, its close proximity to the Cascade Mountain Range and the presence of five major rivers in the valley (Figure 1). The climate of Squamish is highly influenced by the Pacific Ocean and is characterized by very wet mild winters and warm dry summers. Squamish has traditionally been a resource-oriented town that was particularly reliant on forestry; however, in the last 20 years the population has grown and expanded considerably in the area, largely due to its proximity to the City of Vancouver. Squamish is seeing increasing acknowledgement for its recreational opportunities, including world-class skiing, climbing, mountain biking and wildlife viewing. Moving forward, the District of Squamish is challenged to manage considerable population growth pressures, the region's complex terrain, a changing economy and an increasing number of residents commuting to Vancouver for work.

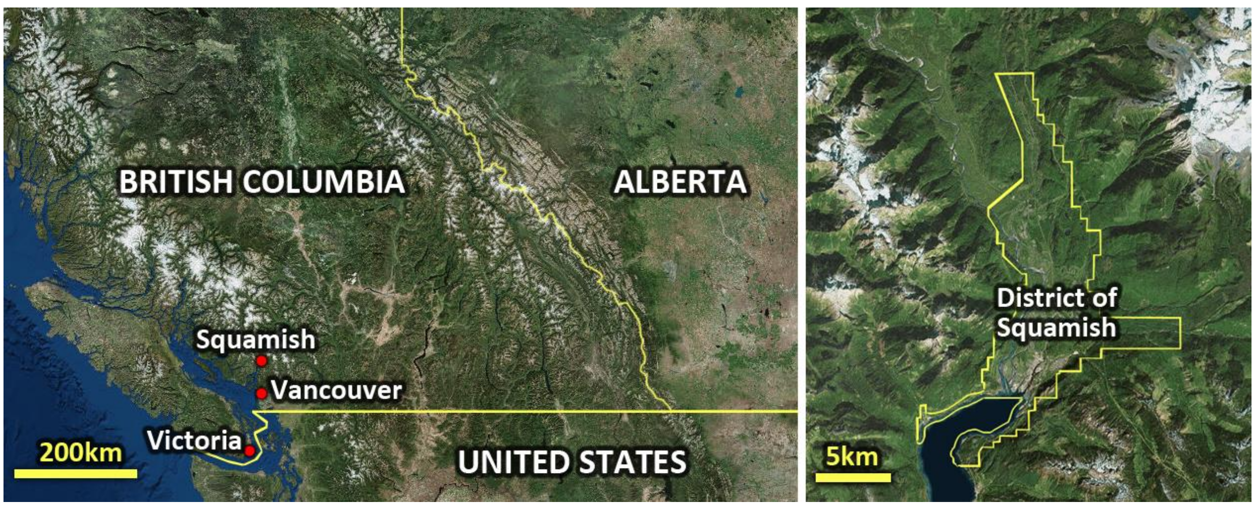

Figure 1. Location and map of Squamish. Base map was retrieved from the Government of British Columbia's iMapBC system.

3. Methods

This research developed a systems model and community scenarios based on the input of local government and stakeholders in order to incorporate community participation in the design of a scenario modelling exercise. The primary methodological challenge of this model/scenario development approach process was to determine how to translate the thoughts and ideas of community members into a systems model and scenarios. Asking study participants to simply identify key 'elements' and 'relationships' of their community systems and potential future scenarios likely would constitute tasks that are too abstract to be performed effectively. Therefore, data collection instead involved engaging participants in discussions on the challenges facing their community and their aspirations for its future. Outcomes of these discussions were subsequently analyzed and used to identify key model elements and relationships. Collecting and analyzing the data in such a manner allowed participants to provide thoughts and ideas based on their experiences, concerns and values for their community, which can then be used as the basis for systems and scenario modelling.

Data used to develop the systems model and define the community scenarios were collected primarily using focus group methodology. An initial focus group session first involved a smaller advisory group from the District of Squamish, and it served to ground the research in the local context and create a draft of development scenarios. The second involved a larger group of local government and community stakeholders, and it served to refine (or potentially develop new) scenarios, as well as identify elements and relationships within the systems model. An ethical review was conducted prior to performing this research, and all participants read and signed research consent forms before engaging in focus group activities.

3.1 Local advisory focus group

The first focus group served as a 'preliminary meeting' and involved four members of the Community Planning and Infrastructure Department. This type of meeting is important, as researchers should first meet with governing groups to gain a sense of local planning realities before engaging in broader stakeholder discussions (e.g., Newell et al., 2017a,b). In this case, local planners were selected as they have direct involvement and expert knowledge in the planning challenges and potential strategies for Squamish. The purpose of the session was to gain insights into local planning challenges, develop rough ideas for possible community development scenarios, and identify neighbourhoods that are of particular interest in terms of future development planning. The session was held in a meeting room at the District of Squamish municipal building, and it lasted 1.5 hours. The focus group began with a presentation on the research and its objectives, and then the group engaged in discussion that was guided by the following questions.

- What are the major planning and development challenges Squamish currently faces?
- What would community development scenarios would be realistic for Squamish, that is, what types of development patterns are plausible for the community?
- What neighbourhoods would serve as good examples of those that would be particularly altered by the scenarios?

Data consisted of audio recordings of the discussion and researchers notes, and these data were examined in order to identify key factors and considerations for developing rough scenarios relevant to Squamish. These scenario ideas provided a useful 'starting point' for further scenario development (Amer et al., 2013), and they were used in the subsequent focus group to stimulate discussion. In addition, particular neighbourhoods were identified by the focus group participants as those that could be used as potential sites of hypothetical redevelopment when exploring the scenarios. The neighbourhoods were selected based on the expert knowledge of planners, who identified a variety of different types of neighbourhoods (e.g., residential, rural residential) that would each (likely) experience significant changes if Squamish took a particular development path. The purpose of selecting neighbhourhoods was two-fold: (1) it provided areas that could be altered in scenario modelling process (Newell and Picketts, 2019a,b) and depicted through visualizations (e.g., Newell et al., 2017a,b), and (2) it gave examples that could be discussed in the second focus group to better ground the discussion in real-world local places.

From the data and analysis, a series of rough community development scenario ideas were created, which involved different development patterns that could be applied to the neighbourhoods. These were then distributed to the members of the first focus group for review and comment to confirm the scenarios were based on the focus group, and did not misrepresent or exclude significant ideas that emerged from the discussion.

3.2 Community stakeholder focus group

Potential participants for the second focus group were identified by the researchers through an online search and snowball sampling (i.e., some invitees suggested others that could be valuable and interested participants). The primary criterion used to build the invitee list was to ensure the group consisted of a mix of people from private, public and non-profit sectors and collectively represent a range of social, environmental and economic interests. Approximately 30 people were invited to the focus group through an e-mail recruitment letter sent to the individual (i.e., not a mass e-mail or public announcement), and 15 accepted, with 12 ultimately attending. Each participant was specifically selected due to their knowledge and involvement with the community; thus, this method follows other research involving small focus groups of people with specialized knowledge (Onwuegbuzie et al., 2009). The participants were diverse and represented a range of groups, including non-profit, local government, elected official, business interests, private developers, transportation authority and academia.

The stakeholder focus group session ran for approximately two hours. The session began with a presentation and discussion on the research project, as well as the rough scenario ideas developed through the focus group. Participants were then arranged into two similar and representative breakout groups to provide more opportunities for feedback. They were asked to comment on the scenario ideas, as well as provided other ideas for scenarios (and ‘potential futures’ for Squamish) that were not captured through these ideas. Participants provided comments through group discussions (which were recorded) and feedback forms, both of which solicited comments on the following questions.

- Comment on the suggested scenarios. What could be added to or changed in these scenarios?
- What are some other development directions or changes in Squamish that you would like to explore in scenarios?
- What might be a desirable ‘potential future’ (i.e., goal) for Squamish (at the community and/or neighbourhood level)? Please describe what this (or these) might look like.
- What are key questions that emerge when exploring a particular scenario?
- What are the major planning and development challenges Squamish currently faces?

Following the breakout session, participants gathered for a plenary discussion. In the plenary, the researchers firstly summarized main ideas from each breakout group discussion, and then the full group was invited to comment on these ideas or add further thoughts. Following the summaries, the researchers facilitated a conversation aimed at focusing and finalizing ideas for community development scenarios that can be used in the modelling and visualizations phases of the project, and this discussion was guided by the question: "What are some development directions or changes in Squamish that you would like to explore in scenarios?".

3.3 Data analysis

Data consisted of transcripts of the recorded discussions and written comments provided through the feedback forms. Data were analyzed through thematic coding methodology (Gibbs, 2007; Seidel and Kelle, 1995), using a coding framework developed by the researchers based on common themes that emerged through the discussions. An initial coding framework was developed based on the researchers notes from the focus group, and then this framework was revised after reviewing the full dataset (Boyatzis, 1998). Altogether, 32 codes were applied to the data, and coding was done using NVivo (v. 11).

The codes were arranged into broader categories, and these categories were examined to reveal the main concepts and ideas emerging from the discussion (as per Saldaña, 2009). These are described in this research as the 'model considerations' for developing a systems model and community scenarios. The systems model was developed in a manner that was consistent with the elements and relationships that were defined in the considerations. The community scenarios were designed/refined in a manner that ensured that all the considerations could be explored through the differences between these scenarios.

After identifying the model considerations, relationships between systems elements were 'mapped' to create a comprehensive picture of the model. This process employed a method similar to Newell et al. (2018), which involved first recategorizing codes into model element types and then organizing them into a matrix to examine and understand relationships between them. The model considerations provided the context for the element type categories, and four categories were defined: model drivers/constraints, land use types, development strategies, and community outcomes. Once relationships were defined, the model was visualized using yEd Graph Editor (v. 3.17.2), and this model depiction provided a clear picture of the different 'scenario outcomes' (i.e., the community outcome elements). Through a review of primary and grey literature, a series of metrics and measurements that could serve as potential indicators for these outcomes were identified. These indicators were further refined through follow-up conversations with individual participants, in which other potentially interesting ways of measuring community outcomes based on available data were discussed. More details on these follow-up conversations will be presented in a forthcoming publication on the modelling process.

Ultimately, three outputs resulted from the data analysis: (1) the considerations for model and scenario development, (2) the community systems model, and (3) the community development scenarios. It is worth noting that the scenario modelling exercise can be conducted using only the latter two outputs; however, identifying the model considerations is important for facilitating a participatory process for two reasons. Firstly, these considerations represent the main ideas that emerged through the local government and stakeholder discussions, and thus, both the systems model and community scenarios must represent a means for exploring these ideas. Secondly, the considerations provide a clear concept of and rationale for how the systems modelling exercise will be conducted, which is important when reporting back to the community on the next steps and proposed approach for conducting the exercise. The considerations, systems model and scenarios were documented in a report that was distributed among the participants, and they were invited to comment to identify any key aspects that appeared missing or misrepresented.

4. Results

4.1 Preliminary scenario considerations and ideas

The first focus group discussion primarily centered on how future development could either support or impact a variety of aspects of Squamish, including public transportation, active transportation, community health, employment, natural networks (i.e., undeveloped lands, wildlife corridors and habitat), local viewshed (i.e., landscape views experienced from within the community), agricultural capacity, and the economic/commercial viability of local businesses. From the discussion a series of questions emerged that were deemed to be important considerations for developing scenarios:

- What are the density thresholds for achieving high levels of walkability and supporting transit and business (i.e., will walkability and transport increase as density increases or does a threshold have to be first reached)?
- How dense can a neighbourhood become before experiencing trade-offs, such as loss of viewshed?
- How will all of the changes lead to shifts in overall community health?
- How can growth be accommodated while still maintaining (or increasing) natural networks?

Much of the discussion on planning concerns and considerations was framed in terms of density. For example, when discussing transportation and community health, the group considered the densification needed to support public transit and encourage active transportation. As another example, employment and economic viability was discussed in terms of the densification needed to support neighbourhood businesses. From the analysis of this discussion, four rough scenario ideas were developed that essentially represented a range of densities.

1. Low density residential neighbourhoods
2. Medium density row housing and low-rise condo neighbourhoods.
3. Medium density primarily condo neighbourhoods
4. High density vibrant community nodes

The discussion also involved determining which neighbourhoods could be redeveloped in a manner defined by the scenarios in order to maintain a reasonable scope for the modelling and visualization exercises (i.e., rather than hypothetically redeveloping every neighbourhood in Squamish). Participants expressed that places with defined neighbourhood plans (such as downtown Squamish) could make for interesting visualizations; however, they do not provide realistic opportunities for modelling different types of development patterns as their development pathway is set. Instead, the neighbourhoods suggested for scenario modelling and visualization were those that did not have extensive new development already planned and approved, and that were also priority areas for neighbourhood planning. Three neighbourhoods were selected: two that are primarily residential suburban and one that consisted mostly of rural residential development. The rural residential was noted to be a particularly good neighbourhood for this project because it has few residents and is not located near a commercial centre, making it a ‘blank slate’ for modelling and visualizing scenarios.

4.2 Modelling considerations

The main ideas and themes that emerged through the local government and stakeholder discussions (i.e., the second focus group) are described in this research as the 'model considerations' for developing the systems models and community scenarios. In total, 10 model considerations were identified, and they capture a collection of planning challenges, local values and concerns, and potential futures that the participants are interested in exploring.

Thematic coding analysis (Boyatzis, 1998; Gibbs, 2007; Saldaña, 2009; Seidel and Kelle, 1995) was used to identify the considerations and tease out the main themes from the focus group discussion, and Table 1 lists the considerations with their associated codes. This section elaborates on each consideration, how they were discussed in the focus, and what guidance they provide for the scenario modelling exercise.

Table 1. Data coding and considerations for informing systems model and community scenario development.

Consideration	Codes
Squamish is growing	Population growth, Current development patterns
Development has been planned and approved	Residential neighbourhoods, Downtown development, Current development patterns
Local employment spaces are important	Regional commuters, Local employment, Commercial space, Mixed-use development
Explore a range of densities	Missing middle development, Aesthetics and visuals, Density extremes, Housing availability, Land use efficiency, Shared lots and infill
Determine an 'optimal density'	Walkability, Economically viable nodes, Transit networks, Corridor-based development, Mixed-use development, Community attitudes
Create an accessible community	Access to green space, Access to education, Access to amenities, Connectivity, Transit corridors, Walkability, Mixed-use development, Community health, Air quality, Greenhouse gases
Develop communities with diverse housing types	Mixed-use development, Mix of housing types, Missing middle development, Social diversity, Shared lots and infill
Housing affordability is a problem	Mix of housing types, Housing affordability
Developing all land as residential is not necessarily desirable	Access to green space, Preserving natural space, Food and farm systems, Steep slope development
Squamish is in a floodplain	Floodplain issues, Smaller homes

Squamish is growing – Focus group participants emphasized that Squamish has a rapid population growth, citing the 13.7% population increase that occurred between 2011 and 2016. With this in mind, a 'no growth' scenario was deemed to be unrealistic, and all scenarios should include population growth which differ in how the population increase is accommodated (i.e., high density residential neighbourhoods, downtown density, etc.). In particular, participants referred to a growth pattern that would result in a local population of in the mid-30,000 range within 20 years (District of Squamish, 2018).

Development has been planned and approved - Many development projects within Squamish have been approved, and thus new residential units will be available in various parts of the community regardless of future decisions. These developments should be included in the different scenarios in order to ensure the scenarios reflect expected housing availability. Once these units have been added, the remainder of the projected population can be accommodated through different development patterns (as defined by the scenarios).

Employment spaces are important - Employment spaces and opportunities frequently emerged as a topic of interest, in particular the need for local employment for boosting local economic development and reducing commuting distances. In addition, although employment land can be integrated into mixed-use developments, it was noted that some areas should remain zoned as solely commercial/industrial because residential zoning can make these places unaffordable for businesses. Such a consideration is important for modelling as it indicates that some scenarios should look at maintaining separation between commercial and residential areas.

Explore a range of densities - The scenario ideas that emerged from the first focus group centered on different residential densities, and the second group agreed that this was worthwhile to explore. Suggestions were made to explore extremes for residential density, from large, single-family houses to high-density, high-rise buildings; however, it was noted that defining 'high-density' could present challenges as this term means different things to different people (e.g., buildings that are 5 storeys, 10 storeys, etc.). Suggestions for addressing this challenge included characterizing density based on other developments in Squamish, or deriving density classifications through reviewing relevant literature. In addition, it was also suggested to include a 'missing middle' density form, which consists of a mix of housing types such as a such as bungalow court, duplexes, multiplexes and row houses (Parolek, 2015).

Determine an 'optimal density' - In addition to a range of densities, the idea of 'optimal density' was discussed. This refers to the level of residential density required in neighbourhoods for local businesses and transit to become viable. For the latter, it was also noted that transit viability can be achieved through developing along corridors rather just in nodes. Optimal density can guide certain scenario development as it can provide neighbourhood population targets that are needed to achieve potential community benefits from densification. The ability of neighbourhood visualizations to effectively model viewsheds was highlighted as an aspect of the project that may help define and refine what 'optimal density' means in Squamish because a major trade-off experienced from densification is obstructed views.

Create an accessible community - The focus group discussion on density and mixed-used form covered considerations around access to services and amenities, including green space and schools. For the latter, it is important to consider both physical access to schools and the student capacity of the schools as the population grows. Access to services and amenities was also noted to relate to questions around walkability and the health and other community benefits received from developing compact, walkable communities; however, it was noted that a health outcome is exceptionally hard to model or quantify. Accordingly, it was discussed that health benefits could be explored through proxies, such as numbers of people engaging in active transportation and reductions in air pollutants resulting from decreased vehicular traffic. The latter was also noted to have the added benefit of reducing greenhouse gas emissions.

Develop communities with diverse housing types - In addition to density, the groups discussed the mix of housing types within a neighbourhood. It was expressed that developing neighbourhoods with a diversity of housing options (including affordable housing) would allow people to reside within these neighbourhood throughout different stages of their lives and also encourage social diversity.

Housing affordability is a problem – A lack of affordable housing in Squamish was noted to be a significant issue. Although it is difficult to predict future market prices of houses, the modelling could approximate housing affordability by considering the mix of housing options available in different scenarios (i.e., does housing consist of just large, single-detached units or are smaller units available?).

Developing all land as residential is not necessarily desirable - The rural residential neighbourhood that was initially identified as a good candidate for scenario modelling was later noted to be a valuable space for agriculture. Building on this comment, scenarios could involve reserving land for purposes other than residential, such as agricultural or commercial/industrial development. In addition, the importance of maintaining natural spaces was mentioned, and one comment framed this in terms of avoiding ‘overdeveloping’ the land. It was discussed that the scenarios could involve steep slope development to accommodate more residential units without occupying valuable valley floor space. However, as mentioned in the focus group, it is worth recognizing that development on hillsides could have viewshed impacts (which is a trade-off that could be explored through visualizations).

Squamish is in a floodplain – Focus group participants highlighted the fact that many neighbourhoods in Squamish are located within a floodplain. This dictates the types of residential units that can be built in these areas, and it creates challenges for building certain types of dwellings, such as smaller housing units (e.g., ‘tiny houses’). Avoiding floodplain development by encouraging steep slope development was identified as a possibility for one or more of the scenarios.

4.3 Systems model

A systems model was developed in accordance with the 10 model considerations listed above. The elements in model were based on the codes used to analyze the data, and the nature/types of these elements were informed by the considerations (Table 2). Categories of elements types featured in the model include drivers/constraints, land use types, development strategies and community outcomes. Most model elements directly corresponded with a particular code; however, in some cases (particularly with land use type elements), new codes/elements were created based on other codes to clearly and concisely capture elements important to the model (as per the model considerations).

Table 2. Data coding and systems model elements

Element type	Element	Codes
Driver/constraint	Population growth	Population growth, Current development patterns
	Land availability	Current development patterns, Land use efficiency, Preserving natural space
Land use type	Residential space	Residential neighbourhoods, Housing availability
	Commercial space	Commercial space
	Agricultural space	Food and farm systems
	Green space	Preserving natural space, Access to green space
Strategies	Density	Density extremes, Downtown development, Shared lots and infill, Land use efficiency, Community attitudes
	Mixed-use development	Mixed-use development
	Mixed housing types	Mix of housing types
	Missing middle	Missing middle development
	Corridor development	Corridor-based development, Transit corridors
	Smaller houses	Smaller homes
	Steep slope development	Steep slope development, Floodplain issues
Community outcomes	Access to amenities	Access to amenities
	Access to schools	Access to education
	Access to green space	Access to green space
	Preserving natural space	Preserving natural space
	Transit accessibility	Transit networks
	Reduced traffic and commuting	Regional commuters
	Air quality	Air quality
	Greenhouse gas emissions	Greenhouse gases
	Health	Community health
	Food and farm	Food and farm systems
	Local businesses	Local employment, Economically viable nodes
	Local employment	Local employment
	Social diversity	Social diversity
	Housing affordability	Housing affordability
	Walkability	Walkability, Connectivity
	Viewshed	Aesthetics and visuals

Figure 2 provides visual representation of the community systems model and the relationships between systems elements. These relationships were derived from analysis of a coding matrix, and they were defined in accordance with the 10 considerations. The elements driving and constraining systems dynamics in the model are population growth and land availability. The former refers to the need to provide an increasing population with housing, employment, services, etc. The latter relates to various competing land uses, such as residential, commercial/industrial, agricultural and green space (i.e., the land uses frequently discussed in the focus group).

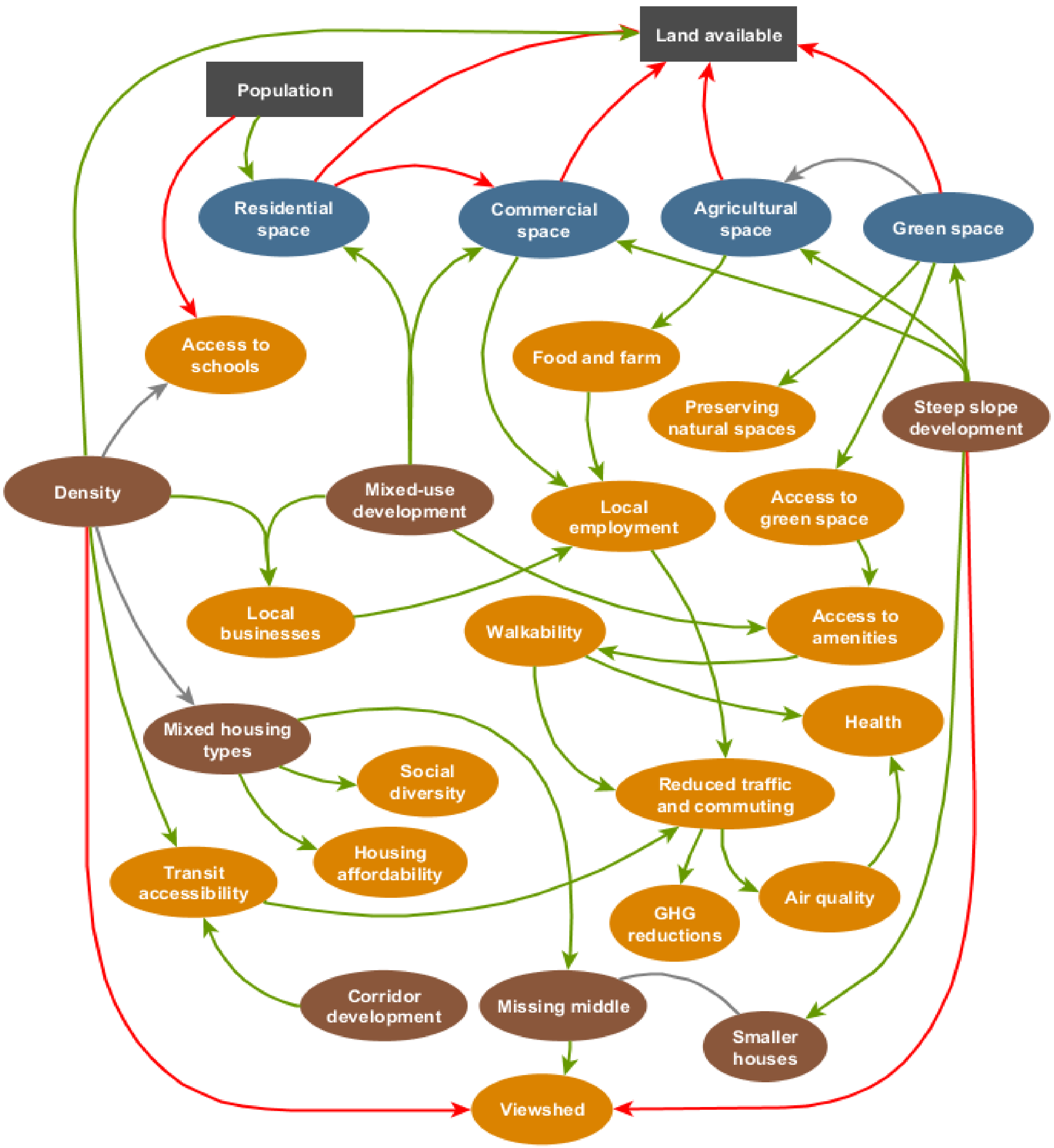

Figure 2. Integrated systems model for examining community scenarios.
Population growth and available land are represented using dark grey nodes, and types of land uses are represented using blue nodes. Strategies are represented with brown nodes, and community outcomes are represented with orange nodes. Green connecting lines refer to positive relationships between variables (e.g., a strategy or community outcome promoting another community outcome), and red connections refer to negative relationships (e.g., a challenge or trade-off). Grey connections refer to relationships that are positive or negative, depending on how a strategy is executed.

The systems model features development strategies/approaches such as densification, mixed-use development, corridor-based development, smaller housing units, missing middle density, mixed housing types, and steep slope development. The strategies have implications for a variety of community outcomes, including access to schools, food and farm systems, local businesses, local employment, access to green spaces, access to amenities, walkability, community health, reduced traffic and commuting, air quality, social diversity, affordability, transit accessibility and viewshed quality. For example, mixed-use developments can increase local employment by adding commercial space in addition to residential units, which (subsequently) can reduce regional commuters. In some cases, the systems model characterizes nature of a relationship between a strategy and outcome as dependent on how a strategy is executed. For example, density can increase access to schools, but only if densification occurs near schools and does not overburden a school in a particular catchment.

4.4 Measuring community outcomes

The systems model provided guidance on what should be measured in a quantitative modelling exercise, in particular the community outcome elements. Through a review of academic and grey literature and (later) conversations with research participants, a series of potential measurement methods were identified for the various systems model outcomes (Table 3). In some cases, the review did not explicitly identify a particular method for calculating an indicator, rather it served to stimulate thinking about relationships between various fine grain aspects of a community and possible ways to quantify these. In addition, it was recognized that the methods could change as data is collected and the modelling processes develops; however, identifying and compiling these methods provides a valuable launching point for the scenario exploration.

4.5 Community development scenarios

The scenarios were refined based on the analysis of the stakeholder focus group data. All scenarios assume population growth will continue to occur in Squamish, and it will follow a growth scenario identified by the District of Squamish (2018), reaching approximately 34,000 in 20 years time. The scenarios examine different development patterns for accommodating this growth, and they look at ways of developing housing for the new residents (after currently approved developments have been taken into account).

For the most part, the refined scenarios (Table 4) followed a density pattern in a similar manner to the scenario ideas developed through the first focus group. However, the refined scenarios did differ from the initial ideas in that other land uses were incorporated (e.g., commercial, agriculture), as well as geographical aspects such as developing on hillsides rather than valley floors. In addition, residential forms were made more explicit in the refined scenarios, in particular mixed-use buildings and missing middle development.

Table 3. Community systems model outcomes and potential measurement methods.

Model outcome	Potential measurement methods	Relevant literature
Access to amenities	• Distance to green space, schools, health, restaurants, grocery stores (i.e., walkability)	Burke and Brown, 2007; Manaugh et al., 2013; Sturm and Cohen, 2014
Access to schools	• Distances from residences to schools • School space per number of children	Burke and Brown, 2007; BC School District 48, 2015
Access to green spaces	• Distances from residences to parks and trails • Park area per person within a neighbourhood	Cohen et al., 2007; Sturm and Cohen, 2014
Preserving natural spaces	• Residential, commercial/industrial and agricultural land encroaching on green space and habitat • Residential density near critical habitat and sensitive ecosystems	BC Ministry of Water, Land and Air Protection, 2004; Wade and Theobald, 2010
Transit accessibility	• Density around transit stops and routes • Distances from residences to transit stops (both existing and potential) • Estimated public transportation ridership	Millward et al., 2013; Ontario Ministry of Transportation, 2012; Vuchic, 2005
Reduced traffic and commuting	• Estimated change in number of vehicle kilometers travelled	Larsen et al., 2010; Iacono et al., 2008
Air quality	• $PM_{2.5}$ emissions based on vehicle kilometers travelled	Cai et al., 2013; Peitzmeier et al., 2017
Greenhouse gas emissions	• CO_2e emissions based on vehicle kilometers travelled	BC Ministry of Environment, 2016
Health	• Air quality variable • Estimated numbers of people walking based on distances from residences to employment (i.e., walkability)	Cai et al., 2013; Peitzmeier et al., 2017; Larsen et al., 2010; Iacono et al., 2008
Food and farm systems	• Amount of land reserved for agriculture • Distance from residences to food services • Distance from high-density residences to community gardens	Baker, 2004; Mendes et al., 2008; Millward et al., 2013
Local businesses	• Amount of space reserved for commercial/industrial • Number of nearby residents to support local businesses	District of Squamish, 2015; Easton and Owen, 2009
Local employment	• Amount of space reserved for commercial/industrial purposes • Number of potential jobs produced through new businesses and employment space • Percent of population commuting outside of Squamish	Ali et al., 2011; Lange and McNeil, 2004; District of Squamish, 2015
Social diversity	• Inferred through the level of diversity in housing types within a neighbourhood	Talen, 2006
Housing affordability	• Inferred through using average prices for different housing types and mixes of housing types	Aurand, 2010
Viewshed	• Assessed through visualization	Newell et al., 2017a,b

Table 4. Community development scenarios refined through stakeholder input.

Scenario	Description
Single-detached family housing neighbourhoods	All development beyond that already planned will be single-detached family housing (i.e., low density). Land use in the neighbourhoods will solely consist of residential units, and it will not involve mixed-use development.
Missing middle development and mixed housing types	Neighbourhoods will be (re)developed with a mix of housing types such as bungalow court, duplexes, triplexes and fourplexes. Missing middle densities can reach up to 35 dwelling units per acre (Parolek, 2015), and some space can be reserved for parks and a retail.
Medium density townhouses in community nodes	Neighbourhoods will be (re)developed with townhouses and mid-rise buildings, and these can be concentrated along transit corridors. When accommodating the same level of population in the neighbourhoods as done in the missing middle development scenario, this form of development can leave more space for commercial, parks, community spaces, and public gardens.
Medium density and hillside development	Neighbourhoods will be (re)developed with medium density buildings along transit corridors in the neighbourhoods, while also developing on hillsides to reserve valley floor space for other uses. Valley floor space will be reserved for agricultural and commercial development in particular, and each of these can be modelled as a 'sub-scenario'.
High density development nodes	Neighbourhoods will be (re)developed with high-density, mixed-use buildings and commercial centres. Densification will occur around transit corridors and commercial centres. Some area will be allocated for green space, and the height of residential buildings will be influenced by this allocation (i.e., more storeys are need to house new residents when less land is made available for residential buildings).

5. Discussion

Systems models can be highly effective tools to help guide community planning and development (Almeida et al., 2009). Given their inherent complexity, it can be tempting for researchers to rely on their expert knowledge of community systems to design the models and experiments; however, it is important for the tools that guide community decisions to be informed by those affected and who live with said decisions. Engagement processes have demonstrated value for developing integrated models for environmental management and planning (Prell et al., 2007; Woodward et al., 2008), and it could be argued that participatory modelling is particularly important in the community planning context as it explicitly involves the places where people live, work and play. Community systems and scenario modellers should act as facilitators of community needs rather than expert knowledge providers (Ling et al., 2009). In simple terms, this can be regarded as the modeller/researcher ‘connecting the dots’, while community stakeholders ‘provide the dots’.

In addition to the principled argument for participatory modelling, this approach to systems modelling and scenario design has other distinct advantages. Once advantage is that it provides a realistic scope for creating a systems model. The multitude of interconnected systems associated with a community can present an overwhelming challenge for those attempting to use systems modelling for urban planning (Sperling and Berke, 2017). Even when attempting to focus a community systems model on a particular community aspect or action, this level of complexity can still create challenges. For example, Newell et al. (2018) developed community systems models that centered on climate mitigation and adaption, which resulted in seven different models due to the plethora of relationships involved in the systems. The participatory approach employed provided invaluable guidance for defining the scope of the system. The key community issues (e.g., population growth, commuting, available agriculture land) and aspirations (e.g., walkability, access to amenities, local employment) identified connections to be elucidated in a model that are relevant to Squamish, based on available information, and of a reasonable scope (in terms of using for quantitative scenario modelling and simulation).

Another advantage of employing participation in systems modelling is that it can aid with data needs. Integrated systems models require a large amount of data, and data gaps are a common issue in this type of work (Prell et al., 2007; Sperling and Berke, 2017). Engaging a community can elucidate what data has already been collected by government and community organizations, and is available for building a model. Such data sources can increase with the diversity of engaged individuals. For example, in this study, local government participants identified sources for data such as road networks, building footprints and approved development, and non-governmental organization participants involved in food security issues directed the researchers to agricultural land and food asset data. In addition, community engagement can ensure that a modelling effort builds on previous work. In the case of Squamish, efforts had already been made to project population growth (District of Squamish, 2017), assess employment land supply and demand (District of Squamish, 2015), and inventory planned development (District of Squamish, n.d.). These previous efforts can be incorporated into scenario modelling work in order to identify key assumptions for the model (e.g., what the population will be in 20 years), determine how (or even if) to model certain aspects of a community (e.g., employment space and jobs), and ground the model in real-world circumstances (e.g., future residential building stock). The latter is essential for enhancing understanding and increasing community literacy about the interrelationships of sustainable community development.

Finally, the participatory approach to modelling employed in this research was advantageous in terms of creating connections between the researchers and community members. This finding is consistent with previous work that has found community-based participatory research to be beneficial for building researcher-community partnerships and social capital (Hacker et al., 2013). The connections made in the focus groups opened opportunities for following up with the participants to gain further insights on where to source more data and how best model certain aspects of the scenarios. Such opportunities for further conversation are valuable because the time available in focus groups sessions is limited, and also it is difficult to determine all information needs for building the model in the initial design stages. By involving stakeholders in the early stages of a modelling, the model becomes relevant to the interests and needs of participants (both professionally and personally), thusly increasing their investment in the project.

The research also resulted in many practical outcomes that are valuable to both the District of Squamish and other local governments. The modelling considerations (Table 1) can become an excellent resource or starting point for other municipalities looking to engage in similar modelling exercises, evaluate development approaches and/or engage in sustainability planning. Additionally, the existing systems model can be used to conceptualize (and applied to quantify) the myriad relationships between development strategies and their implications on community outcomes (Table 3). The resultant information could become invaluable in informing community planning efforts, including those related to land use policy (e.g., District of Squamish, 2018), climate change adaptation (Picketts et al., 2012), and transportation networks (e.g., Vuchic, 2005; Wagner and Wegener, 2007).

The participatory approach employed in this research was done in two stages: first involving a small advisory focus group, and then involving a larger community stakeholder group. This approach held both advantages and potential issues. The major advantage of this methodology was that (as anticipated) it provided a strong starting point for the larger focus group discussion. Sheppard et al. (2011) describe a framework for participatory climate planning that recommends a similar process, where initial scenario ideas are developed by researchers and then refined through community engagement processes. The potential issue with the approach used here is that it may have constrained participant imaginations in terms of devising scenario ideas, as was evidenced by the fact that the refined scenarios did not significantly differ from the density-based scenarios characterized through the initial scenario ideas. It is possible that the participants would have been interested in exploring a density range regardless; however, the similarities between the initial and refined scenarios bring forward questions on whether there is a balance to be struck between focusing a discussion and enabling co-creativity in participatory modelling processes.

Ling et al. (2007, 234) note that “a small group representing diverse sectors of a community is more valuable than large group of like minded people”, emphasizing the importance of including and representing multiple perspectives within a planning process. The systems model developed in this study benefited from the multiple perspectives that provided input into its design, as it incorporated a variety of different social, economic and environmental considerations relevant to the community. However, it is important to recognize that, in a participatory modelling process, the extent a systems model represents a community is entirely dependent on those who could and could not make it to the engagement sessions. In this study, the focus group was relatively small (12 people), and certain invitees with specific interests and knowledge were unable to participate, thus potentially underrepresenting these interests. For example, invitees with strong ecological interests and knowledge were unavailable, and although habitat considerations were captured in the model, it is possible that other ecological concerns significant to Squamish were not made explicit enough (e.g., watershed issues, endangered species, etc.). To address this challenge, it is best to regard models as tools that can be continually developed as more user engage with it, rather that a ‘final product’. Newell et al. (2017a) recommend a similar process for creating visualizations for planning purposes, arguing that since these tools require capturing large amount of detail and a wide variety of elements, they should be continually developed as more stakeholders interact with them. In a similar vein, systems models can be continually refined and developed as more people have the opportunity to interact with and provide feedback on them, and indeed, this approach has been employed in the second stage of research (Newell and Picketts, 2019a,b). Ultimately, such iterative participatory modelling processes will lead to tools that better represent a community and its planning needs.

6. Conclusion

Community engagement and participation is a necessary component of effective community planning and (more broadly) sustainable community development (Ling et al., 2009). Accordingly, the tools and techniques used to support planning efforts should also incorporate participatory processes in their design and application. This research explores such an approach in the design of a community systems model, which is subsequently serving as the basis of ongoing scenario modelling and visualization project.

It can be tempting for scenario modelling researchers to develop models and scenarios based entirely on their knowledge (and other academic work). However, when these models have implications for community planning, it is important to involve stakeholders to ensure modelling procedures and processes align with sustainable development principles and best planning practices. By using a participatory approach, modelling exercises can be designed to be highly relevant and useful to the community's needs, concerns and values. This being said, participatory modelling can still lead to 'gaps' or deficiencies in cases when certain community members are unable to attend engagement sessions and their interests are not adequately represented by those who are in attendance. However, by providing capacity for iteratively refining and further developing the models, they can continually evolve into tools that more accurately reflect the community and are increasingly effective for supporting integrated community planning and sustainable development.

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